USER ACCEPTABILITY OF PHYSIOLOGICAL AND OTHER MEASURES OF HAZARDOUS STATES OF AWARENESS

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SUMMARY

Two studies explored user acceptance of devices that measure hazardous states of awareness. In the first study, critical incident data were collected in two workshops from 11 operators working as air traffic controllers or commercial pilots. These critical incident data were used to develop a survey of the acceptability of awareness measures. In the second study, the survey was administered to 100 people also working as air traffic controllers or commercial pilots. Results show that operators are open to the inclusion of technology to measure HSAs even if that technology is somewhat invasive as long as feedback about the HSAs is considered to be useful and helpful. Nonetheless, a major concern is the legal complications associated with being recorded, particularly for older and more experienced operators. Air traffic controllers emphasized the importance of sharing technology information with supervisors in order to receive backup or assistance under conditions of task overload, whereas pilots emphasized the influence of work schedules on problems with awareness. Recommendations are offered concerning the implementation of devices to measure hazardous states of awareness.

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I. INTRODUCTION

Vigilance is a natural requirement for most organisms to monitor their environment for events such as potential dangers, food sources, and mates. These events occur often at random, and an organism must be continually ready in order not to miss an event. Vigilance is also a requirement in the operation of many of the machine systems that serve humans. For example, most adults drive automobiles and must monitor the external driving environment (e.g., speed, the behavior of other drivers, road conditions) as well as their internal states (e.g., fatigue, boredom). There are clearly more demanding and complex systems such as those for the air traffic controller or the pilot of a high performance aircraft. Indeed, the development of automation in complex systems has made monitoring a primary task of the human operator.

One well established fact of human vigilance is that there is a pattern of rapid decrease in awareness (Davies & Parasuraman, 1982). With some systems, vigilance decrements occur within 30 minutes (e.g., Mackworth, 1948). Although a considerable amount of research has examined factors affecting awareness and continued vigilance, many practical and scientific questions still need to be addressed (See, Howe, Warm, & Dember, 1995; Warm, 1984).

Hazardous States of Awareness

Of paramount interest in monitoring complex systems is the possibility of extending the period of effective vigilance and awareness. Under routine and habitual working conditions, operators may experience losses of attention that can result in a degradation of performance. Prolonged periods of decrements in performance can lead to dangerous and even deadly outcomes. Collectively, these losses of attention are referred to as hazardous states of awareness (HSAs).

Several HSAs can be identified that are troublesome in complex systems (Scerbo, Freeman, & Mikulka, et al., 1998). For example, a performance block occurs during a time period in which there is no productive output, even though the operator is engaged in the task at hand. Operators do not cease to respond in the task environment, but they are preoccupied with other task stimuli or thoughts. Performance blocks typically increase in frequency with increased time working on repetitive tasks.

Boredom is another common HSA, and it is associated with monotonous work. Boredom occurs when a sufficient level of arousal cannot be maintained to perform the task. When an operator ceases to be stimulated by a task, arousal decreases, and boredom sets in.

Complacency refers to excessive trust in equipment or automated systems. When working under familiar circumstances, there is a tendency to rely overly on machines or computers. As a result, the operator does not monitor the system and fails to detect its signals, anomalies, or malfunctions.

Mental fatigue is a state of tiredness and inefficiency that interferes with performance on a task. Lack of rest or sleep contribute to mental fatigue. A person who is mentally fatigued has difficulty allocating attentional resources to different tasks, and this results in a decline in performance. Although mental fatigue shares some commonalities with boredom, fatigue appears to be a distinct phenomenon.

Mind wandering occurs when thoughts intrude into consciousness that are unrelated to the task at hand. This flitting from thought to thought may be a natural consequence of sustained and selective attention, because it often occurs with performance on vigilance tasks. In contrast to a performance block, mind wandering appears to involve task-irrelevant thoughts.

Measures of Hazardous States of Awareness

Three types of measures can provide information on the presence and occurrence of HSAs: (1) subjective reports of awareness, (2) behavioral and performance measures, and (3) physiological measures. Each of type of measure has costs and benefits. For instance, subjective reports may be inaccurate, and the process of reporting about awareness may distract the operator from ongoing tasks.

Byrne and Parasuraman (1996) discuss the potential utility of physiological measurement. Such measures could be available during performance and provide continual information about the levels of awareness with minimal or no distraction for the operator. Researchers have examined various indices of awareness: Eyeblink rate (Krivolahvy, Kodat & Cizek, 1969); heart rate variability (Hartley, Arnold, Smythe & Hansen, 1994); and electroencephalogram (EEG) measures. For example, Pope, Bartolome and Bogart (1995) used various EEG bandwidths in an adaptive automation system to maintain operator vigilance. Their method employed feedback from an EEG index of arousal in an attempt to keep the operator at an optimal level of arousal. Freeman, Mikulka, Scerbo and Prinzel (1999) extended this effort and found evidence that the use of an EEG index could enhance the performance of the operator in a visual tracking task. Follow-up research has used this technique to reduce the magnitude of the vigilance decrement for a monitoring task (Mikulka, Hadley, Freeman, & Scerbo, 1999).

There are several important issues in the assessment and use of physiological measures to improve monitoring and aid operator vigilance. First, it is necessary to demonstrate that a given physiological measure is effective in maintaining performance. Although previous research is supportive of this requirement, many performance-related factors still need investigation (e.g., the effectiveness of the physiological measures over extended performance sessions and for a variety of tasks). Second, physiological measures must be feasible in an operational environment. This includes not only the technical aspects of measurement but also the associated acceptability of the measures themselves to the operator. It is well known that user acceptability is critical in system design (Scerbo, 1995). Third, there should be sufficient benefits to the operator from the information made available by the measures. Indications of the presence of HSAs must be helpful in taking corrective actions (e.g., a pilot engaging the autopilot, a truck driver pulling over to rest). Although benefits are key to the introduction of physiological measures into complex systems, effective utilization of the measures always depends on user acceptance.

The purpose of this research is to explore user acceptance of physiological and other measures that aid performance in complex automation systems. Two studies are conducted.

The first study involves applying a methodology known as the critical incident technique to develop a survey to explore user acceptability. The second study involves administration of the survey to operators of complex systems to investigate the acceptability of potential devices for measuring HSAs. Based on the resulting information, features of design are identified for measures of HSAs as well as areas of concern in the implementation of the measures.

II. STUDY 1: CRITICAL INCIDENT WORKSHOP

Critical Incident Technique

The critical incident technique has been an important research tool for more than four decades. The technique was originally developed by Flanagan (1954) to obtain a specific behaviorally focused description of work and other activities. A good critical incident has four characteristics: (1) it is specific; (2) it focuses on observable behaviors that have been, or could be exhibited; (3) it describes the context in which the behavior occurred; and (4) it indicates the consequences of the behavior.

Critical incident data are collected initially by asking subject matter experts to recall examples of particularly effective or ineffective work behaviors they have witnessed, performed, or learned from others. Researchers then edit these data for clarity and redundancy, and a content analysis is often conducted to identify themes or "facets" that underlie the behaviors described in the incidents. Collectively, the behaviors and facets are utilized to construct behavioral statements. The result of this process is a domain of facets and behaviors that can be used for a variety of purposes.

Most typically, critical incident data are used to develop performance evaluation instruments (e.g., Latham & Wexley, 1981), but they can also be used for training needs analysis (Goldstein, 1993), training program design (Campbell, 1988), and areas of concern for adapting operators to new work requirements (Latham, 1988; Pulakos, Arad, Donovan, & Plamondon, 2000). It is this latter usage that we propose for the critical incident technique.

Participants and Procedure

Six air traffic controllers (ATCs) and five commercial pilots participated in a half-day workshop. A complete set of workshop materials is given in Appendix A. Each participant was paid $200 for time in the workshop. All participants were males.

Phase I. Participants were given a brief overview of five HSAs described previously, and why they are considered hazardous. They were then instructed to think of each HSA and provide written descriptions of effective, ineffective, and typical ways of dealing with HSAs. Examples of critical incidents were given to participants so they would have an idea of the type of information they should provide. The examples were taken from the Aviation Safety Reporting System (ASRS) database (http://asrs.arc.nasa.gov/). The ASRS is an anonymous reporting system for ATCs and pilots. Reports include a narrative of the problem and a description of the corrective action that was taken, if any. A search was conducted of the database to find reports that were illustrative of HSAs. These reports were modified and used as examples for the workshop.

Participants were given detailed instructions on how to write good critical incidents and were asked to work individually to generate them. Participants were told that incidents did not have to be limited to personal experiences but could include those learned from work colleagues. Their stories were to include a background of the incident, a description of the actions or behaviors and equipment that were involved, and how the incident affected work performance. Each participant was asked to generate two incidents for each of the five HSAs.

Phase II. The second phase of the workshop involved a discussion of the critical incidents that were generated by the participants. The goal of this discussion was to obtain information about aspects of the work situation or the person that indicates when an HSA is likely to occur. Participants were also asked to offer suggestions on how to deal with the HSA.

Phase III. In the third phase of the workshop, participants were asked to speculate on new equipment, procedures, and devices that could be used to help reduce the incidence of HSAs. Two examples of physiological measurement devices that might improve vigilance in complex systems were introduced. The purpose of this portion of the workshop was to find out whether participants thought these devices would be useful, what features would be most helpful in reducing HSAs, what features would prevent them from doing their job properly, and what features would affect acceptability of the measures.

Results

Critical Incidents. A total of 79 critical incidents were generated. Of the total, 19 incidents reflect performance block, 14 boredom, 17 mental fatigue, 13 mind wandering, and 16 complacency. Critical incident data were edited for clerical errors by four of the researchers. Next, these researchers independently assessed each incident on the following criteria: (1) does the obtained incident meet requirements for being a critical incident (i.e., specific, observable behavior, context, consequences); (2) does the incident illustrate its proposed HSA or can the incident be considered an example of another HSA; and (3) is the incident a good example of the HSA and if not, should it be deleted. As a group, the researchers discussed each critical incident and a consensus was reached on assessment. The final set contained 9 incidents that reflect performance block, 7 boredom, 16 mental fatigue, 12 mind wandering, and 13 complacency (see Appendix B). Three incidents were considered to be examples of more than one HSA. There were several critical incidents that did not illustrate any of the original five types of HSAs. Some suggested themes for the ancillary critical incidents are forgetting ($\underline{n} = 5$), task overload ($\underline{n} = 7$), underprepared ($\underline{n} = 4$), and preoccupied ($\underline{n} = 12$). The ancillary incidents are presented in Appendix C.

Workshop Discussion. The ATCs stated that they were more effective when they were in charge of more aircraft, because they tend to pay less attention when they are in charge of fewer planes. They felt that their supervisor should be called upon to assess critical situations, but indicated that younger and older operators may be reluctant to ask for help. Younger operators may feel that asking for help will undermine their intentions to prove themselves to be capable workers. Older operators face a different problem, because they are typically more experienced and have established themselves as experts. These operators view themselves as the individuals who other operators come to for assistance, and not individuals who seek assistance. Asking for help may undermine the expertise and reputation that experienced operators have sought to achieve and maintain.

A main concern of ATCs is poor communication with pilots due to faulty radios. They thought that visual feedback would be useful to supplement and verify any verbal communication. They also suggested that the altitude dialed in by pilots should be data linked to an ATC's control panel so that even if something was heard incorrectly, it could still be corrected. Improving the accuracy of the information that ATCs receive and send to pilots is viewed as a critical factor in the smooth functioning of the overall system.

The ATCs viewed technology as positive so long as it was not intrusive. They wanted smarter equipment that would evaluate what was looked at by an operator. One device they thought would be useful was a visual scanning device. The scanner would rotate between screens, flight strips, and runway and would be calibrated to check eye movements. The device would alert the operator with an alarm when he or she had not paid attention to an area after a period of time. Once the operator looked in the direction indicated by the alarm, it would shut off. The ATCs preferred that the device "look" at eye movements from overhead or a console instead of requiring that a headset be worn. The ATCs in the workshop expressed interest in helping in the developmental of such a device and indicated that participation would impact their acceptance of the device.

The pilots stated that while automation could reduce their task load, manual skills could also be used to prevent HSAs. Unfortunately, they felt that older pilots are less trusting of automation and newer pilots have less manual skills. They indicated that the majority of errors occur during takeoff and descent. A suggestion they had to combat errors was to employ memory aids. They also suggested that adherence to standard operating procedures could prevent errors (e.g., running checklists). Strict adherence to procedure is not always done, especially when tired. Staying alert and awake was cited as being especially problematic. Strategies they said they used to stay alert were taking naps, drinking coffee, standing up, and talking. They thought it would be useful to have a device to alert them when they were falling asleep. They attributed part of the difficulty with staying alert to poor work scheduling (i.e., flying several flights in succession without enough rest in between).

The pilots were open to new technology, however they emphasized that it was not simply more technology, but more appropriate technology that was needed. They were not opposed to the use of technology if it was used to decrease task overload. They suggested that warning sounds and messages could be used to indicate when something was wrong. Furthermore, onscreen instructions could inform and direct them to the problem. Switches that light up and say "fault" or "turn off" could be used as well. Some concerns they had regarding the use of new technology were the invasiveness of it, being monitored and recorded, and legal repercussions. Mainly, they wanted technology that was convenient, noncumbersome, and gave them appropriate feedback.

III. STUDY 2: HAZARDOUS STATES OF AWARENESS SURVEY

Survey Development

The information obtained from the critical incident workshop was used to develop a twenty-two item survey (See Appendix D). The survey reflects aspects of the system, person, and features that may influence user acceptability of measures of HSAs. The survey is separated into three parts. The first section collects background and demographic information. The second section contains six items that address the existence of HSAs in work situations. Respondents are required to indicate their level of agreement on a 5-point scale; the low anchor (1) is "strongly disagree" and the high anchor (5) is "strongly agree." The third section describes two devices that could be used to measure HSAs. Respondents indicate their level of agreement with eight items related to each device using the same scale as in section one.

Participants and Procedure

The survey was administered to 100 participants from the same work communities as those who participated in the critical incident workshops. Each participant was paid $50 for completing the survey. Of the 100 respondents, 27% were ATCs and 73% were pilots. The majority (84%) of the sample was male. Proportionately, more females were occupied as ATCs (48%) than as pilots (10%). The age of the respondents ranged from 22 to 73 years. The mean age was 42 years. The predominant ethnicity was White (93%). Median experience in the present position was approximately 10 years, and total experience in the present and similar positions was approximately 15 years.

The survey was completed on the worldwide web by most of the participants (94%). Each participant was sent an invitation by electronic mail or was contacted by phone. If the invitation was accepted, an E-mail was sent to the participant containing instructions about the survey. The instructions included a unique username and password as well as the address of the web site for accessing the survey. At the web site, the participant was required to enter the username and password. Once the survey was completed, the participant submitted it. Survey responses were automatically recorded to an electronic data file. After submission of the survey, the participant was directed to a payment voucher that required entry of the participant's E-mail address (for verification and identification of occupation). The payment voucher was filled out, printed, and mailed by the participant to the Old Dominion University Research Foundation to obtain payment for participation.

If a participant did not have access to the worldwide web, a paper-and-pencil version of the survey was sent by mail via the United States Postal Service. Six people (3 ATCs and 3 pilots) were mailed surveys. Because these surveys were returned anonymously by mail, the occupational status of the six participants could not be matched to survey responses. A participant mailed both the survey and payment voucher to the Research Foundation.

Results

Results are presented in three parts. The first part is a description of the correlational analysis of all items in the survey. The second part reports significant differences in the responses of ATCs and pilots, and between the two devices using simple t-tests. The third part is a principal component analysis of the all items, excluding demographic information, to describe the major themes reflected by the survey.

Correlations. Not surprisingly, significant correlations were obtained between the demographic variables of age, experience in the current position, and total experience (See Table 1 in Appendix E). Experience in the current position was significantly and negatively correlated with the everyday occurrence of HSAs ($r = -.23$). In other words, more job experience was associated with a lesser occurrence of HSAs. Further, operators with more experience in their current position were more likely to be concerned about legal issues with the brain sensing device ($r = .20$). Older operators were also concerned about legal complications resulting from use of the brain sensing and eye movement devices ($r = .21$ and .20, respectively). Older operators and operators with more total job experience wanted the option of turning off the brain sensing device when necessary ($r = .28$ and .33, respectively).

With respect to sex differences, women had less total experience ($r = -.21$). Women were less likely to believe that the most probable reasons for human error are HSAs ($r = -.20$), that aspects of work schedule are responsible for HSAs ($r = -.26$), and that the use of manual skills can reduce HSAs ($r = -.29$)

As shown in Table 1, correlations between the occurrence of HSAs, human error on the job, and the use of checklists and other memory aids were significant (rs from .21 to .33). When there were few tasks to perform, respondents indicated that manual skills could help reduce HSAs on the job ($r = .20$). For both devices, if HSAs were believed to occur when few tasks are available to perform, there was less worry about the legal implications of being recorded ($r = .22$ and .22, respectively).

If operators perceived aspects of the work schedule to be largely responsible for HSAs, they tended to be worried about legal complications arising from using the brain sensing device ($r = -.25$). Furthermore, operators who attributed HSAs to work schedule, wanted the option of turning off ($r = .22$) and were worried about legal complications ($r = -.20$) from using the eye movement device.

Table 1 shows that the perceived usefulness of feedback was significantly correlated with willingness to use the brain sensing and eye movement devices (r = .61 and .59, respectively), even if the devices are somewhat invasive or cumbersome. The more useful the devices were viewed for giving feedback, the less the concern about being recorded (r = .27 and .42, respectively). Furthermore, the more useful the eye movement device was viewed for giving feedback, the less the concern about the legal repercussions from being recorded (r = .32).

Feedback from either device was significantly correlated with task underload and task overload situations (rs from .25 to .35). Significant relationships were obtained between willingness to use each device and recording of activity level, legal complications, task underload, and task overload (rs from .22 to .61). Concern over being recorded was significantly correlated with legal complications, task underload, and task overload (supervisor only) for both devices (r from .20 to .34). If an operator was not concerned over being recorded then it was less likely that he or she would be worried about legal complications for both devices (r = .56 and .67, respectively). Signaling coworkers to help in the task overload situation was significantly related to concern over being recorded with the brain sensing device (r = .20). With the eye movement device, legal complications were less likely to be considered problematic in task underload situations in which additional tasks were given to perform (r = .21). Legal issues were less of a concern when supervisors were signaled to help in task overload situations for both devices (r = .20 and .32, respectively). Being given additional tasks to perform in task underload situations (eye movement device only) was significantly correlated with signaling one's supervisor and coworkers in task overload situations (r = .28 and .20, respectively). Reactions to signaling one's supervisor or coworkers in task overload situations were significantly correlated for both devices (r = .51 and .60, respectively).

T-tests. Independent t-tests were performed comparing mean responses of ATCs and pilots to the survey items. Results are presented in Table 2 (see Appendix E). Pilots reported experiencing more HSAs than did the ATCs ($t_{(98)} = -2.36$). Pilots considered aspects of their work schedule as more likely to be responsible for experiencing HSAs ($t_{(98)} = -2.90$). Pilots considered memory aids and using manual skills as more useful for reducing HSAs than did the ATCs ($t_{(98)} = -2.16$ and -2.76, respectively). In task overload situations for the brain sensing device, ATCs considered signaling their supervisor to provide help as more useful than did the pilots ($t_{(98)} = 2.04$). Finally, ATCs were less worried than the pilots about the legal implications of recording eye movements ($t_{(98)} = 2.38$). However, ATCs and pilots were similarly concerned about legal implications associated with the brain sensing device.

Paired t-tests were performed to compare the brain sensing and eye movement devices. Results are presented in Table 3 (see Appendix E). Three significant differences were found. The eye movement device was considered significantly more useful than the brain sensing device ($t_{(98)} = -2.03$). Respondents indicated that they would want the option of turning off the brain sensing device to a greater extent than the eye movement device ($t_{(98)} = 2.14$). Finally, for task overload situations, it was relatively more important to link brain activity levels than eye movement activity to the supervisor ($t_{(98)} = 2.35$).

Principal components analysis. Principal components analysis with varimax rotation was performed on the survey items. This was done to determine the primary "themes" reflected in the survey items. Eight components were extracted with eigenvalues above 1.0. Component loadings and percents of variance are shown in Table 4 (see Appendix E). Interpretive labels are tentatively suggested for each component.

The total variance in the survey accounted for by the eight components is approximately 77%. Item loadings range from .61 to .92. Component 7 (Scheduling) is defined only by one item. Components 4 (Task Underload), 6 (Option to Use), and 8 (Reducing HSAs) are each defined by two items. The two items defining Component 4 (Task Underload) are highly correlated ($r = .88$) and less so with the remaining items. The two items defining Component 6 (Option to Use) show a similar pattern of a strong correlation ($r = .50$) and weaker correlations with the remaining items. Items loading on Component 8 (Reducing HSAs) are not strongly correlated ($r = .20$) with each other. Clearly, the stability and interpretation of components defined by one or two items is tenuous and should be viewed with some caution.

Components 1 (Legal Concerns), 2 (Task Overload), and 3 (Device Use) are each defined by four items, and Component 5 (HSA Occurrence) is defined by three items. Component 1 reflects a major concern of respondents of being monitored and the legal ramifications associated with monitoring. This component accounts for 15% of the total variance in the survey. Another strong theme is having coworkers and supervisors alerted in situations where the operator is feeling overloaded (Component 2 accounts for 14% of the total variance). Finally, willingness to use the devices was also a strong theme (Component 3 accounts for 13% of the total variance).

IV. CONCLUSIONS

Detecting HSAs in complex systems is an important first step in improving the period of effective vigilance and decreasing the incident of accidents. Physiological measures are one way in which information can be obtained about an operator's performance. The present research addresses the acceptability of such measures of HSAs in two aviation-related occupations. One of the goals of this research was to gain insight into the features of HSA indicators that affect user acceptability.

ATCs and pilots both acknowledged the occurrence of HSAs in the workplace. For ATCs, boredom was mentioned as a factor that impacted their job performance. The ATCs who participated in the workshop enjoyed being busy. When they were not, they found it difficult to stay awake. Another concern of ATCs was improving communication with pilots. Pilots reported experiencing more HSAs than did ATCs. Task overload and fatigue were the major problems encountered by pilots in their work. Staying alert was also an issue for pilots, however, the problem was fatigue-related not boredom. Pilots attributed the occurrence of some HSAs to poor work scheduling and indicated that memory aids and manual skills could help combat the problems associated with HSAs.

In general, ATCs and pilots were open to the inclusion of technology so long as it was not overly invasive. ATCs thought devices could help improve their vigilance by signaling when they were in trouble. Furthermore, ATCs were more favorable towards signaling their supervisor than were pilots. Perhaps pilots lack the opportunity to receive help from others in their work environment, or they are expected to deal with problems on their own. Pilots want technology to decrease their task load and to signal them when their arousal level has dropped to a dangerous level. Pilots were open to indicators such as alarms, onscreen directions, and flashing lights and switches. Ideally, the technology would also indicate what corrective action was needed. In this way, the devices can serve a diagnostic purpose and assist the operator in making the necessary changes in the work situation. Overall, the critical incident workshops revealed that the appropriateness and usefulness of the feedback given are contributing components in user acceptability of any devices used to measure HSAs.

Correlational analysis helped to identify major issues and relationships of concern. Results show that workers with less job experience encounter more HSAs. Working conditions, in which operators are unsure of how to perform or are overly stressed, become hazardous and interfere with effective job performance. In fact, respondents indicated that HSAs were associated with committing errors on the job. It may be necessary to monitor HSAs in less experienced workers and make sure they are handling the situation properly.

Workshop participants indicated that the usefulness of feedback was related to their willingness to use the devices. Principal components analysis linked these two items into one component. The analysis also showed that concern about being recorded and legal complications is a major issue. The survey helped to reveal that the more useful the device was considered to be, the more likely it would be used even if it was somewhat invasive and the less concern there would be over being recorded. Useful feedback regarding a state of awareness appears to abate concerns over being recorded and any legal complications, particularly for the eye movement device. Respondents indicated that it was essential that they receive good feedback when underloaded and overloaded. In situations where workers feel overloaded, getting help from a supervisor was desired, particularly when using the brain sensing device. Legal concerns were especially salient among older workers and workers with more experience using the brain sensing device. With the brain sensing device, the option to turn it off may increase acceptability. Overall, both ATCs and pilots considered the eye movement device more useful. However as the frequency of HSAs increased, concern over being recorded decreased for both devices, suggesting that safety concerns outweigh legal concerns as HSAs become more prevalent in the work environment.

In summary, this research has demonstrated that ATCs and pilots experience HSAs at work, and each occupational group deals with them in different ways. Both groups are receptive to new technology to measure HSAs, even if that technology is somewhat invasive. An important point to emphasize is that the device used to measure HSAs must give useful and helpful feedback to the operator. Nonetheless, being recorded and legal ramifications are major concerns, particularly when the devices are viewed as invasive and operators are older and more experienced. Including the option to turn off devices may play an important role in the willingness to use them. Finally, getting backup or assistance from a supervisor under conditions of task overload is important, especially for ATCs.

We offer several suggestions for improving the acceptability of physiological measures of HSAs. It is critical that operators receive useful and timely feedback concerning their state of awareness, particularly when it becomes hazardous. A warning signal of some kind needs to be incorporated into system design that will alert the operators when they are in trouble and what corrective action needs to be taken. When operators feel overloaded, it may be necessary not only to signal an operator but the supervisor and coworkers as well. The recording of activity level and legal concerns are strongly linked. Operators need to be assured that measurement devices are in place solely to improve safety and are not to be used against them in legal actions. They also need to have some control over the use of the device. The option to turn off the device may be one way to accomplish this need. Finally, less experienced workers need to be monitored closely as they may be more susceptible to experiencing HSAs because they have less practice in dealing with them. Older, more experienced workers need training so they fully understand the purpose of the measurement device and that it is in place to help them and not to take away their discretionary control.

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APPENDIX A: WORKSHOP MATERIALS

Good morning! Welcome to a NASA sponsored workshop on Hazardous States of Awareness. We call them HSAs, and they are natural human processes. Most people have experienced HSAs in driving their automobiles. A driver may stopped at a signal light thinking about a needed vacation and fail to notice the light has changed. Of course, the driver is likely made aware of the light change by honking cars. HSAs also occur during checkout at the grocery store. Most people pay some attention to ring-ups as well as the bagging and collection of purchased items. However, a customer may not attend to each scanned item or to every action of the bagger. After all, scanning is done electronically, and the items are in open display at the pick-up counter. However, miss-rings and left behind items are often discovered after returning from the grocery store.

HSAs are frequently merely annoyances. There is little about them that is hazardous. However in complex systems, they can result in dangerous and deadly outcomes. What we are going to do today is have you generate some examples of HSAs that occur in your job situations. We call them critical incidents. These critical incidents may reflect your personal experiences of dealing with HSAs, but may include incidents learned from work colleagues.

We would like you to generate critical incidents for five types of HSAs that occur in complex systems. The five types of HSAs have general descriptions:

> <u>Performance Block</u>: Delayed performance during task engagement.
> <u>Boredom</u>: Insufficient arousal to perform the task.
> <u>Complacency</u>: Unwarranted trust that equipment or system is operating properly.
> <u>Mental Fatigue</u>: Perceived tiredness and inefficiency in performing a task.
> <u>Mind Wandering</u>: Thoughts unrelated to the task.

Here are some example descriptions of these HSAs that we have found in safety reports (*Note—each set of HSA and descriptions was given to participants on a separate page*).

<u>Performance Block</u>: Delayed performance during task engagement.

We departed Bakersfield, CA enroute to Phoenix, AZ. Ten minutes into the flight we were given a clearance to go direct Palmdale VOR. Not long after receiving this clearance, we had a yellow caution annunciator illuminate, "Cabin Duct Hot!" Being preoccupied with taking care of this small problem, as well as handling the radios and arranging some charts, I did not notice that a strong west wind had blown us East of our course. ZLA brought this to our attention. I don't know if we encroached on Bakersfield MOA or not. But we may have. Anyway, this heavy workload combined with minimal rest period the night before caused me to be somewhat slow and recognizing our situation. Also, we did not have time to eat breakfast before going to the airport. Both of us were tired. I think that had I been more alert (less tired) I would've been able to deal with these events without any problems.

I relieved into sector 10 and radar and data positions. Proper relief briefing was initiated, but was distracted by aircraft X calling. He was VFR 5500 feet asking for clearance. ATC told me about aircraft Y at 6000 feet, but I lost awareness of him. Aircraft Y was non-radar and X was radar contact. There was some confusion over the Spencer altimeter setting. My first notice of aircraft Y was limited data block 10 o'clock, 10 miles from X because I didn't believe there was any other traffic in the area. I believed the limited data block to be a split Beacon from aircraft X. Both strips were in the bay, but I only processed one. I called the TFC to aircraft X, and even told him that the TFC might not be real. He acknowledged the TFC in sight, and that is when I realized there was something amiss. I made a blanket broadcast for TFC in the Spencer area. I then noticed the strip on aircraft Y. I issued X an immediate dissent to 5000 feet. TFC missed by 1-2 miles and 500 feet.

Boredom: Insufficient arousal to perform the task.

We were flying the pattern in left closed traffic, landing on runway 25. After one hour of touch-and-goes, I was somewhat bored. I heard the pilot of the inbound aircraft call for a missed approach. We turned crosswind and I heard the ATC authorize the frequency change to mugu dep for the pilot calling the missed approach. The student turned downwind at approximately 800' agl. As we climbed toward pattern altitude of 1045', I noticed what appeared to be the red and green position lights of aircraft approaching ours, head-on, less than 1/4 miles in front of us! I immediately initiated a left descending turn to the student's amazement and confusion. When I contacted the tower to inquire about the near miss (estimated at 200' vertically and 200' horizontally), the tower was unsure who the tfc was. Later, they indicated it must have been the individual flying the missed approach.

As we started leveling at fl230, ATC asked us to verify altitude. We stated fl230. ATC asked us our assigned altitude; we said fl210. ATC said descend and maintain fl210, which we did. Auto pilot failure to capture altitude selected fl210. Failure to monitor instruments. Repeated takeoffs and landings between two cities bred complacency, boredom, and fatigue.

Complacency: Unwarranted trust that equipment or system is operating properly.

This flight was a routine trip from PHX to ONT. Due to departure familiarity, the captain's takeoff brief was abbreviated. On departure, the squawk was incorrect and departure control asked us to change it as the FMC entered "low ALT capture" mode. The first officer became task saturated as he attempted to set the aircraft speed bug to clean maneuver speed and change the IFF. The aircraft accelerated to approximately 290 knots at 3500 feet MSL. Additionally, lateral NAV guidance in LNAV showed us slightly L of the BUCKEY 2 SID 240-degree heading. At this point, approximately 8 miles from PHX the captain, seeing the command bars indicating a R turn, commenced a R turn to AVONA. Departure control directed us back to a 235-degree heading.

It was late in the afternoon of our fourth day of flying, and captain was at the controls. Visibility was four miles (MVF) in haze at DFW, so we were vectored for and an ILS to runway 31R at DFW. We were cleared for the approach, and I made all of the appropriate callouts, including "no flags, gear down, cleared to land." After we landed, I realized that we had not switched to TWR frequency, and were still on approach. I told the captain, and he instructed me to contact the tower. I did and the controller ask if I had heard his xmissions. I confessed that we had not switched to his frequency, and apologized. He said not to worry, and gave us further instructions. I believe that the cause of this deviation from the regulations was complacency. It had been visual approaches all week, and we had not "geared up" our minds for a "real" ILS approach. I lost focus and made the callout "cleared to land" without giving it any meaning. I was just going through the motions.

Mental Fatigue: Perceived tiredness and inefficiency in performing a task.

Commenced recurrency from 9 month layoff with BFR on APR/TUE/95 and APR/THU/95. On MAY/TUE/95 completed 10 touch-and-goes at HPN when tower cleared me for full stop due mounting inbound IFR traffic. Exited runway, stopped, cleaned up airplane. Decided to fly HPN-CMK-CROTON-HPN to practice VOR tracking and departed RWY 11, forgetting to turn on xponder. Called N90 3-5 MI E of Croton Point and received/entered squawk code recognizing at that instant that xponder was off. Corrected. Moments later saw a bizjet pass off to L in front of my plane. N90 reprimanded me on the radio and I acknowledged my error.

The incident took place on the final landing after 6 legs, 14 duty hours, and 8 flight hours. Flight PFN to ATL was being vectored to Atlanta Hartsfield by Atlanta approach control frequency 127.9. Just prior to the other marker for runway 9R, we were switched to approach 118.35. At that point we were told to keep our speed up as long as possible for intrail traffic. Also we were landing behind a (ACR) 757. We intercepted the LOC and GS visual. I was going through landing checks and waiting for flaps setting commands. I was extremely busy and neglected to switch to TWR 119.1. We were in final configuration at 500 feet AGL. The TFC ahead had cleared the runway some time ago. The captain made a normal landing and exited at the first high SPD. I realized my mistake and looked at #1 radio which still had 118.35 approach control dialed in. I switched to tower and reported holding short of runway 9L at B6. Tower than cleared us to cross and taxi to our assigned ramp.

Mind Wandering: Thoughts unrelated to the task.

On February, Thursday, 1999, flight X was being operated under far part 121, EWR and FLL. I was first officer and PF on this flight and had received clearance to level off at 6000 feet after departure. I was hand flying the airplane on the initial departure for pilot proficiency, and had intercepted the outbound course on the SID. The SID was fairly complicated (Newark 6, white transition). I had become preoccupied with horizon navigation and failed to anticipate the approaching level off at 6000 feet MSL until I was already passing 6200 feet. I immediately arrested declined and ascended back down to the assigned altitude, but not before total deviation of 300-400 feet from assigned altitude had occurred. Standard procedure for our airline calls for the PNF to advise the PF aloud when we are within 1000 feet of the assigned level off altitude so that the PF is aware of the approaching vertical clearance limit, and can begin slowing his vertical rate to avoid an altitude deviation. In this case I received no alert of any kind for the PNF of the approaching altitude assignment. When I questioned him about it, he remarked that was my leg and it was my responsibility to adhere to any and all clearances.

I inadvertently descended below minimum safe altitude while orbiting over a traffic accident for long period of time. The aircraft was configured for slow flight with flaps partially extended. I believed that the problem arose because of the repetitive tasks involved with orbiting for long periods of time. After arriving at the scene of the accident, I reduce power and extended flaps and took up orbiting. I chose to orbit at 1600 feet MSL based on the CRQ altimeter setting. Based on information on my class B terminal chart, I determine that the terrain was approximately 500-600 feet above sea level, 1600 feet would place me 100 feet AGL. After orbiting for approximately 30 minutes, I realized that by the view out the windows and by the altimeter that I was well below my chosen altitude. I immediately added full power and climbed back to 1600 feet MSL and continued orbiting. I feel that while using the auto accident as a pivot point for orbiting, scanning for other traffic and constantly adjusting the power to compensate for the turbulence, and speculating on how the traffic accident occurred that I neglected to look at the altimeter and take corrective actions sooner.

Critical Incident Story

Think about an HSA incident reflecting _________. You may have personally encountered this HSA, or have heard it discussed by colleagues. Focus your attention on the incident and what was extremely effective or ineffective in the situation. Consider these set of questions in writing your story.

1. What were the general circumstances leading up to this incident? In other words, what was the background or situation of this incident?

2. What exactly did the individual do that was ineffective or effective? What actions or behaviors were involved? What equipment was involved?

3. How is the incident an example of ineffective or effective behavior? How did it affect performance?

<u>WRITE YOUR STORY</u>

Strategies for Dealing with HSAs

As a group I would like you to discuss the critical incidents that you generated. Your goal is to identify aspects of the work situation or person that led to an HSA. Let's start here with you (CHOOSE A PERSON). Describe one of your incidents for the group.

Anyone have ideas about how to deal with this hazardous state? Those are good ideas!

Let's discuss another incident. Any volunteers?

Remedies or Devices

I would like to engage you in futuristic thinking about HSAs. I want you to speculate on new equipment, procedures, and other devices that might be available in the next 10 or 15 years to help reduce HSAs. This may include special kinds of monitoring devices that record activity. Please speculate how this equipment could be useful to you. What features would help you perform your jobs? Further, what features should be engineered out of these devices so they would not hinder you doing your job properly?

Here's one example. Suppose that sensing devices are attached to your headset that could evaluate the level of your brain activity. We know that brain activity fluctuates with the amount of energy and focus that a person gives to tasks at hand. Further suppose that the device has been trained to you. That is, a baseline that has been established for you that reflects your optimal level of performance. When performance deviates from the optimal level, the sensing device activates. You could be signaled either directly through the headset or perhaps by a display. The signal could indicate that you are becoming overloaded by tasks, or that you need to take a rest break. It could also indicate that activity has fallen to an extremely low level. You may be prompted to perform other tasks to increase activity.

Another kind of device might be a miniature camera that is attached to your head set. This camera follows and records the movements of your eye. It also establishes a baseline of activity that considers the person, the nature of tasks, and the priority of information that needs to be processed. When eye movements stay away too long from critical locations or information, signals are forthcoming either through the headset or through displays. The signals would prompt the operator to re-focus attention to a particular location or set of information.

As a group, please address these questions:

What other kinds of equipment or devices do you envision?

How might this equipment help to deal with HSAs?

Do you think that operators would actually use such equipment?

What features of the equipment might hinder acceptance?

APPENDIX B: CRITICAL INCIDENTS

Performance Block

1. This seems to be a recurring problem with lots of crews. Our aircraft is EFIS equipped with flight management system. The indication that we are flying flight management system is the white course needles and the flight management system green icon on the FMA. When the pilot flying briefs the approach we engage the heading mode temporarily so that the localizer inbound course can be set. This involves switching from white to green and back to white needles again. Normally the next step is the reselection of the flight management system push-button however, this process happens in conjunction with several other tasks. The pilot flying is briefing the approach to be flown and usually the pilot not flying is intermittently talking with the air traffic controller as we are descending for the approach. Invariably, sometimes the flight management system button is not selected. Normally the deviation is very small. The airway is 4 miles wide and we rarely get more than 2.5 miles off. However, aside from looking directly at the FMA, the most usual indication of this missed task is just by looking at the flight management system map on the multi-function display. For me, the best way to alleviate this problem is to brief the approach while in cruise before the descent is started and the workload is low. Another time the missed selection occurs is when the crewmembers are engaged in conversation.

2. Recently, I forgot to run the taxi checklist prior to take-off and the captain never caught this. Of the 15 or so items on the list only 2-3 can really have killer consequences. As I rotated, the aircraft seemed very heavy. The captain said trim! I looked down and it was set for a weight and CG for our last flight. I compensated smoothly while using two hands. This was a huge mistake (could possibly kill you)! Several things were out of place. The weather conditions were poor and we got to discussing what followed some unusual taxi instructions. Next, we started discussing the captain's previous approach into the airport. I forgot the whole thing!

3. I was flying as a MD-80 first officer departing from Chicago O'Hare on a clear afternoon on runway 326. I was turned to the west shortly after take-off and directly into the sun. While climbing to our assigned altitude of 5,000 MSL, the controller directed our attention to a possible conflicting aircraft ahead. I was hand flying (not on autopilot) and attempted to look for the other aircraft while blocking the sun with one hand. These diversions resulted in missing my altitude restriction even though the captain had given me 1,000 feet prior call. Obviously, my performance was degraded through my own ineffective behavior. I became task saturated (i.e., limited visibility and other aircraft) and could have greatly helped myself by going to the autopilot.

4. We were pushing back in Boston in a B-757. The captain appeared very rushed and in a hurry to get going. After a normal start sequence he instructed me to call for taxi. I asked him why now and he said just get it. I read back taxi instructions as he pushed up power. I said to stop as did the tower because the crew were still hooked up to the aircraft.

5. The controller was busy and requested assistance. Everything was then running smooth

but continued to be busy. A DH-8 departed northeast bound and began complaining about his altitude request and the altitude he received. As the assistant was busy changing the DH-8's altitude in the FD-10, the controller began to lose focus and a handle on the position. To quiet the DH-8 pilot, the controller climbed him through the altitude of an inbound C-9. The controller never noticed the incident while trying to recover the position to a smooth operation.

6. The controller was working a moderate to heavy load of traffic. Flights of F-15's were departing and recovering to the Air Force Base. A heavy C-5 came inbound and was too high for descent to the Air Force Base. Because of the slow descent profile of the C-5, the controller issued a spiral descent to 10,000 from 28,000. As the C-5 got comfortable with the pattern, the descent rate increased. The controller was too busy to watch and didn't pick up on it. A flight of F-15's outbound and headed for the C-5 were climbed to 15,000. When they were 5 miles apart, the controller realized the C-5 was descending through 15,700. The F-15's were descended to 14,000 and the C-5 stopped at 15,000. This could have been avoided with better preparation and issuance of paper stops, which are extremely useful during busy periods.

7. It was an instrumental flight rule day in Detroit. We were working on a northeast operation. The controller working arrival west had the motor inbound fix and all the inbounds from the north. While working a heavy arrival push (10-14 aircrafts), the final got pushed out to 15-20 miles. The controller was so focused on turning aircrafts onto the final that he forgot to turn the northbound traffic to the downwind. This caused the traffic from the north to fly directly to the airport and conflict with the east arrivals downwind traffic. The controller didn't scan all the area that he had control over. Proper scanning would have taken care of the situation. The performance after the incident got worse since he was still thinking about the earlier situation.

8. I was working a feeder position at Norfolk. An aircraft informed me of a problem he was having. After spending several transmissions with the aircraft, we determined that he could continue without any difficulties to his destination. When going back to my other aircraft I noticed that I had to make several handoffs and point outs because I didn't scan the scope.

9. The day shift crew had just relieved the midnight crew. The day shift crew was short on personnel. The oncoming supervisor relieved the local controller. Runway 25R was closed because some men were finishing up some work on the runway. The supervisor was trying to accomplish some of her duties as the supervisor (i.e., making phone calls and some paper work). An aircraft called for departure. She cleared the aircraft for departure on runway 25R with the men and equipment still on the runway (luckily on the departure end). The supervisor was trying to accomplish too many duties and tasks. She did not properly scan her runway and because the men and equipment were at the end of the runway it was difficult for her or the aircraft to see.

<u>Boredom</u>

1. This crew flew the exact same 6 ½ flight hour (13 hour workday) trip day after day, month after month. It left JAD and went up the east coast to Worchester, MA. They were over

it! The crew was on an assigned heading and was told to intercept a radial on an airway. They flew 6 miles offshore over the Atlantic (about 1-1½ minutes) before air traffic control asked them where they were going. Both guys had to put down their newspapers and look up to see. This crew was ineffective and complacent.

2. I was a MD-80 first officer flying from San Francisco to Dallas Fort Worth and recovering on an arrival profile that I had flow many, many times. Additionally, I was flying with a very experienced captain, who was probably also bored. The result was a lack of attention and the initiation of a very late descent preventing us from making a published altitude restriction. We realized this well into the descent and embarrassingly told the approach controllers of our problem. Luckily it was somewhat of a slow day. There was no conflicting traffic so the controller was able to delete the restriction. Obviously, our boredom could have resulted in a serious problem and degraded performance.

3. I was a first officer on a B-767 transatlantic flight from Dulles-BRU. The crew did not engage all 3 autopilots for an auto-landing as per standard operating procedure until about 500' AGL. Long, boring all night FCF's make it difficult to gear-up for the final critical phases of flight.

4. We were holding aircraft for the Detroit Airport because we were below minimums and all aircrafts wanted to stay at higher altitudes. All aircrafts were in holding patterns and we didn't have much to do. We became bored and started talking to other controllers in the room. After about 20 minutes, a Zawtop L-188 asked if he should turn north. The controller looked at the radar and didn't see this aircraft on the scope. The aircraft was asked his position and he stated 60 miles south of Toledo. The controller then advised the aircraft to fly 360° and waited until he came back on the radar. All aircrafts were in holding, but this aircraft never acknowledged the instructions to hold. Instead of monitoring the position, the controller started talking to other people and had his back turned to the radar.

5. I was working the local control position at LGB tower combined with ground control. One night it was extremely slow and there were very few operations, I taxied out two BESS aircrafts for departure on runway 30. One aircraft took the intersection mid field and one taxied down to the full length of the runway. The aircraft both called ready for departure at the same time and I put them both on the runway for departure. I got the aircraft's position on the runway backwards and cleared the aircraft at the full length for take-off first, with the other aircraft in position mid field facing away from the departing traffic. Had it not been for observing the distant aircraft on departure roll, the second aircraft would have departed over or collided with the aircraft on the runway. This incident was due purely to boredom and inattention on my part.

6. I was working a Cessna in closed traffic for options (pilot/student practice takeoffs/landings) for about an hour. The routine had been to let the aircraft reach mid field and then to clear him for the option since there were no other aircraft around to sequence him with. I was thinking about (ironically) how slow it was with nothing to do when the Cessna asked if he was cleared for the option. I looked to see the Cessna on base-leg. Continuous scanning of the airport environment would have pre-empted this situation from occurring.

7. A Nighttime operation is a very slow period. An aircraft was requesting taxi to the runway for departure. The controller had not spoken to an aircraft for about 40 minutes. The controller was reading a magazine and pacing the floor. The controller taxied the aircraft to the wrong runway and was not aware of his error until the radar controller advised him. The controller was bored and because it was the only aircraft he had, he was not aware of his errors.

Mental Fatigue

1. The rules for a pilot's workday are out of date, not to mention complex. I had a day where I was over our union's limit and approaching the FAA's limits. I had been away for 15 hours and 56 minutes. I started early in the morning and finished late at night. During the day, we had 2 crew swaps, 2 aircraft swaps, and were on maintenance for 3½ hours. The last leg taxed me mentally. The last leg was in the snow and freezing rain to a runway that had obscured skies and ½ mile of visibility (but at the legal minimums). I felt very behind and made a couple of incorrect call-outs pertaining to altitude as we descended on the approach. The coffee did not help. The captain caught my mistakes and corrected me. He had just been called onto the trip and was well rested.

2. I was flying as a MD-80 first officer. It was a late afternoon departure from DCA through Chicago and then on to Seattle arriving there at 12:30 am SEA time (3:30 am body time). Although I had attempted to sleep as late as possible the morning of this flight, I was up and awake at 9:30, 18 hours prior to my scheduled landing time. Due to a slightly late departure from ORD and several weather reroutes, our actual arrival time was around 4:30 am body time. Myself and the captain were both well behind in everything: radio calls, configuring for the approach, and behind ready to fly the approach. Although nothing adverse occurred, we both remarked on the ride to the hotel how behind we felt and how our performance been decreased due to the fatigue.

3. I was flying as a MD-80 first officer from Dallas Fort Worth to PDX. After leaving the gate at Dallas Fort Worth, we had a 5 hour weather delay on the ramp. The passengers were cranky, the flight attendants were real cranky, and the captain was at wits end. What started out as a routine long day ended up a 14½ marathon. Our mental effectiveness once we got on our way airborne was marginal at best. Nothing unsafe occurred, but the potential was there. The smart thing to have done would have been to call it a day at Dallas Fort Worth, but our Type-A personalities and goal-oriented mind-set made us continue.

4. The crew had a long night due to a case of food poisoning on a South American layover. Some abnormal calls by the ground crew during push back and language difficulties during air traffic control communications caused a tired crew to accept and attempt take-off clearance with only one engine running on a B-757.

5. After a long day (about 14 hours) and as a relatively new captain, I accepted a visual approach clearance to XYZ airport. I confirmed runway 35 in signs and proceeded to set up for a 10 mile straight-in. Approach told us we were lined up on XYZ Air Force Base 5 miles west of our intended destination. I just wanted to get there.

6. It was the 1st leg of the last day of a 4-day trip. All 3 previous days were long and we had arrived late the previous night in Los Angeles with a minimum (9 hours) layover. We left at 7:00 from Los Angeles to Denver expecting good weather (it looked good on CNN). Our forecast showed the weather was to deteriorate just prior to our arrival but this fact didn't really hit home. Enroute, the ATIS broadcasts were all visual flight rules at Denver and we were just cruising along ready to be there. About 10 minutes prior to our descent, an ATIS report came over ACARS indicating a slight drop in the ceiling/visibility. This still didn't register and again, no big deal since we'd be on the ground in 25 minutes. Over the next 15 minutes ATIS changed 6 times ultimately showing a nearly obscured airport. We flew a CAT III approach to CAT II minimums and landed in the middle of a freak snowstorm. Both pilots were fatigued to begin with and were not expecting what they actually had been told to expect. Onboard equipment (e.g., radar, ACARS, autoland systems) allowed us to recover and land safely, but we were unnecessarily put into a last minute panic mode.

7. It was a 2-leg all-nighter coming home to Chicago. The copilot was flying. Standard calls are 2,500' altimeters set, 1,000', and the runway in sight cleared to land. I had to ask for a repeat of the altimeter and a confirmation that we were cleared to land. Too little rest the previous day resulted in being too mentally fatigued during the 2nd all night leg. The use of the other pilot was a good fallback.

8. This is a story of anticipated mental fatigue where effective techniques meant that nothing happened. We were scheduled in an Airbus A-320 to fly from Vancouver to San Francisco, lay over for about 3 hours, then fly on to Dulles International (landing after midnight). Total duty day with briefing time was about 12 hours. Vancouver's weather was good but there were scattered thunderstorms for San Francisco and heavy thunderstorms (with a good chance of a divert) for Washington. The first leg was uneventful, except that we planned ahead and arranged to land on the one runway certified for automatic landings, in case we needed to use it in Washington. The captain spent a good deal of time on the layover studying the weather and concluded with the dispatcher that Syracuse, NY was the closest alternate. The aircraft was full of passengers and cargo so we couldn't add any gas; fuel would be tight. Enroute to Washington, we kept updating our weather information with dispatch through our onboard computer and we were able to change our alternate to Pittsburgh, saving about 1,000 lbs of gas to allow more holding time if needed. On arrival, Dulles approach tried to assign us a non-autoland runway, but with low ceilings, reduced visibility, mental fatigue, and wet runways we insisted on the autoland runway. We also briefed a normal and an autoland approach. Except for the ceiling being lower than anticipated, everything was as expected and we made a normal landing. It was extremely effective to plan ahead and prepare for automated assistance to compensate for fatigue. We also kept alert by talking to each other and to dispatch. The weather radar was a superb tool upon arrival. And yes, Starbucks coffee helped too. This was an example of many effective behaviors that helped our performance.

9. The controller worked in the office and didn't think he would work the floor that day. He had a restless night and was fighting a cold. There were a few sick leaves that day so the controller was called to the floor and assigned the arrival position. The position was busy

and the controller was behind the whole session. Traffic calls were missed and frequency changes were late. A MD-80 was still on approach frequency when he approached the runway and had to go around. The MD-80 had to be vectored immediately to avoid departing slower traffic ahead.

10. The work schedule that we had at the time was 3 nights and days. If you had the midnight, you worked 3 nights, 1 day, and a mid – working a 2 to 10 night shift and then coming back the next morning at 6:00. After getting off work at 2:00 pm, I had to return at 10:00 pm for the mid. I was working the last rush of the day after very little sleep between the 3 shifts. After taking several handoffs, I got behind very fast. I forgot the turn-ons and frequency changes. Luckily, the traffic died and I didn't have much traffic for the rest of the shift.

11. The controller was working a high altitude sector. The weather was instrumental flight rules at EWR and La Guardia. The sector was holding aircraft for both airports. Staffing of the area was low and air traffic controllers were spending almost 2 hours on position. The controller had been extremely busy, rerouting aircraft, coordinating alternate routes, and updating expect further clearance times. Almost all of the holding altitudes were being used. The controller had gotten rid of a few aircraft so he accepted two more. Holding instructions were issued to the new aircraft. Then, the controller realized he had put two aircraft at the same altitude. He immediately issued a descent to Aircraft #1 and turned both aircrafts. Separation was lost. In discussing the event with the controller, he stated he was exhausted and needed a break.

12. After working the midnight shift at Los Angeles Airport, I was held over the staffing problems. I was assigned the final monitor position, responsible for ensuring separation between aircraft on parallel finals at Los Angeles. The arrival controller forgot to give an approach clearance to an aircraft joining the localizer. Without an approach clearance, the aircraft did as it should and flew through the localizer nearly colliding with the aircraft on the adjacent final. I obviously felt very tired and thought I was very slow in picking up on what was happening.

13. I observed an aircraft taxi from ramp towards the runway. Since I did not have a departure strip for the aircraft, I asked ground control who the aircraft was. He advised that he had not taxied anyone out and did not know. We both watched and called to the aircraft as he took the runway and started to take-off. The aircraft finally came up on frequency at the departure end of the runway. I advised the pilot that he had not received taxi or take-off clearances, to which he responded he was aware of that and he was tired from several flights into and out of controlled and uncontrolled airfields, which do not require a take-off clearance. He had unwittingly departed thinking all was well. He then realized his error and came up on frequency to clear things up. No other aircraft were affected and safety was not compromised.

14. A controller was working the local control position in a slow traffic period. The controller cleared a commuter for take-off and taxied a USA jet into position and hold. After transferring the commuter to departure radar, he propped his feet up on the counter and relaxed into his chair waiting for the appropriate separation before he could clear the jet for departure. Within approximately 30-40 seconds, he had fallen asleep in his chair. The

aircraft on the runway checked in again and this woke the controller up. No incident occurred. The controller works a full-time job after this normal controller job. He was not only mentally fatigued but probably physically fatigued.

15. It was a busy arrival and departure session at Los Angeles tower controller or local control for about 2 hours. All intersections between runways were occupied. The controller departed two aircraft and crossed three aircraft that were holding between the runways. A United pilot, still holding between the runway, started to gripe and complain about holding too long. The controller advised the pilot to hold and returned to his duties. After the next departures, the controller crossed the United and 2 other aircraft. A second USA aircraft, with similar call sign as United, started to cross. The controller was busy getting ready to depart an aircraft and noticed USA crossing the runway. He cancelled the departure clearance with no incident. The controller was on position too long during a busy session and was mentally tired. Too many tasks and duties.

16. We departed Dulles airport on a transcontinental flight to Los Angeles in the early afternoon. We sat for 4 hours at the Los Angeles flight operations (as scheduled) then flew on to Denver arriving about midnight (2 am to our bodies). On descent, we failed to press the buttons on our flight management computer to activate and confirm the approach mode. This was probably due to fatigue. Our runway assignment was changed at the last minute due to shifting winds. When we selected computer managed speed (normal procedure) with gear and flaps down, the power immediately went to full throttle and the aircraft almost oversped its flaps. We disconnected the autothrottle and manually flew the approach (a bit sloppily, because we weren't expecting this). We tried twice more to reconnect the autothrottle with the same result. It wasn't until we landed that we realized what mistake we had made. Our checklist usage was ineffective; we should have caught our mistake during the approach check. The automation of the Airbus A-320 will normally sequence into the approach mode by itself but not if the runway is changed at the last minute. Our systems knowledge, which is normally good, was weak that night due to fatigue. It should not have taken us 3 tries to figure out what step we had missed. Our manual flying technique was rusty since we use the autopilot so much and rarely do we find ourselves in a slam-dunk runway change, lose-altitude-immediately situation. This is an example of ineffective behavior. Since the weather was clear (the only problem was strong gusty winds), we did not compromise safety. However, the margin would have been much thinner in instrumental flight rule conditions. (COMPLACENCY)

Mind Wandering

1. With all of the automation in place, it is easy to let your mind wander. I climbed out and remembered passing through 15,000. The next time I remembered looking at the EFIS screens we were at 25,000 and had leveled off and intercepted (turned) our course. It can be a boring (but well paid) job. The legs can be repetitive. Same routes, same call-outs, and everything is predictable. You just start thinking about other more exciting things. I usually try and counter this. After takeoff, I hand fly – this forces me to stay in the loop and pay attention to matters at hand. Once in cruise, I will turn on the automation and sit back. Often, technology has been added to the cockpit to improve things but it only creates new problems.

2. I was a MD-80 first officer flying somewhere to somewhere (too long ago to remember). The captain was flying and was well behind seemingly everything. I had flown with this captain several times and he had always been very sharp in controlling the aircraft but today not so! He had to be reminded of required altitudes, turns, calls to the flight attendants, etc. At one point I even asked if he was ok. He said yes and we pressed on. Nothing adverse occurred but the potential was there. After the flight, he remarked that one of his children had become seriously ill and his father had been diagnosed with cancer. Obviously his mind was not where it should have been and this ineffective behavior degraded overall performance.

3. We were on the last leg of a 5-leg day. We were going into Madison, WI for the night. It had been a long day but a painless one and we were going to be there for 30 hours. It was mid-December and I had not started my Christmas shopping yet. I was thinking that in a college town I would be able to find some of the CDs my teenagers were looking for. We were on final approach for runway 24 and cleared for landing. It was about 22:30 local time and the airport was nearly deserted. As we came over the threshold to land (the captain was the pilot flying), both the copilot and I saw 21 on the runway and yelled to go around the wrong runway. We executed a go-around and came back to a safe landing on 24. When we asked the tower controller if he had noticed us he stated that he had but wasn't concerned since we were the only aircraft in the pattern. None of us caught that the final approach heading (even though a short visual one) was wrong. I didn't because of mind wandering. Last minute cross-checks kept us from potentially landing on an unsuitable runway. (PERFORMANCE BLOCK)

4. We were on a cross-country flight from Dulles airport to Seattle, WA. We crossed snowy intersection at 12,000' as assigned, but missed a radio call to us telling us to continue down to 7,000'. (The transmission was apparently blocked.) When we got the descent, it was quite late. We subsequently were cleared lower (to 4,000' then 3,000'), but we were still high. We should have really hustled down out of 7,000' but didn't. The controller delayed our approach clearance because there was another aircraft landing on a parallel runway and we didn't have it in sight. Both pilots in our aircraft were looking for the other guy, even the pilot flying, who should have been watching the altitude and realizing how tight our situation was becoming. We were cleared for the visual approach at the instrument final approach fix. When we looked at the runway, we both finally realized we were way too high. The pilot flying called for the next flap setting, but we were too fast to lower more flaps so we decided to go around. The basic ineffective act here was the pilot flying allowed himself to be distracted looking for the other aircraft – that should have been the responsibility of the pilot not flying. The pilot flying would easily have been able to make the approach if he had aggressively managed his altitude. Crew coordination was poor in that the pilot not flying should have backed him up and alerted him to the excess altitude. Crew coordination was good at one point when the pilot not flying realized we were too fast to lower more flaps, despite the other pilot's direction to do so. This was an example of ineffective behavior. The weather was clear and the missed approach was flown safely. However, things would have been worse with a low fuel state and an alternate airport involved.

5. Controller A was training Controller B. Controller A was not really paying attention and was talking with other controllers in the room. The trainee got busy and could no longer

handle the traffic load. Three facilities were holding traffic. Instead of the trainer taking over, the trainee had to get his attention. Controller A took over and controlled the situation but a few close calls resulted from his inattention.

6. Controller A was working the high sector. Controller B was working the sector below Controller A. The aircraft departed the low sector climbing to 7,000 feet. Controller B was trying to work out a shift swap and was not paying attention to the task at hand. Controller A climbed the departure even though he had traffic at 8,000. Controller B heard the clearance and advised Controller A to stop the climb. Controller A was more concerned about the shift swap then working traffic.

7. While working the morning shift at Los Angeles approach and feeling under the weather, I decided to ask for sick leave. Due to constant staffing problems, I was told to hang in there for another hour and then I could go home. During the second hour after my request, I was working the departure radar handoff position. I was feeling worse by now and was also mad that I wasn't allowed to go home. There was an unplanned go-around called down to me from the tower, along with the tower assigned aircraft's heading. I relayed to the departure controller the aircraft information but not the aircraft's heading. The departure controller turned the previous departure out of the way of the go-around to ensure separation. The problem occurred when the heading he turned this departure was the same heading given to the go-around and the aircrafts got way too close to each other.

8. Controller A relieved Controller B with a complete briefing. Aircraft X was on a 4-mile final and Aircraft Y was in position on the runway for departure awaiting previous arrival to exit the runway. All of these conditions were active during the briefing. Controller A assumed the position and started to review his pay statement. He realized the critical situation when Aircraft Y reminded him that he was on the runway ready for departure. Aircraft X was on a short final and had to be sent around. Controller A was not totally into the relief briefing and was more concerned about other matters.

9. While working the midnight shift at LGB tower, I taxied out of BE-76 for a visual flight rule flight following down the coastline. After the aircraft was airborne and headed south, I went back to filling out the nighttime paperwork. Several minutes after take-off I received a call from the pilot asking who the traffic was that narrowly passed off his left. Realizing that I had completely forgotten to provide advisories to this aircraft, I looked up at the tower radar display and there was in fact another aircraft headed up the coastline at the BE-76's altitude. I apologized for my inattention and let the paperwork wait until I had safely handed the aircraft off to the next controller. This incident occurred early in my career and scared me with the "what if's" so much so that it has never happened again.

10. During the last day of a 4-day trip, the captain I was flying with became ill during the first leg of 3. The subsequent scramble to get a replacement pilot took 3 hours and threw the day into a complete thrash, but overall it was no big deal, just 2 more legs to Chicago. I'd done it a million times and the weather was fine. The new captain was a bit behind the power curve after being called at home. He was new on the airplane and asked me to fly the first leg so he could catch up. No problem. That leg was uneventful and though we were late, we turned the aircraft quickly in San Francisco and were on our way to Chicago with the captain flying. Yes he was new but he was qualified and we were only going to

Chicago. My mind was on my upcoming days off, what jobs I had to get done at home, and what activities my kids had going on, etc. We began our descent into the Chicago area. It was clear weather and light traffic. As usual, Chicago approach wanted us to keep our speed up, so we did – no problem. We were cleared to continue our descent from 14,000' to 7,000'. I happened to come out of my haze at 10,300' with 320 knots in time to tell the captain to slow down prior to 10,000'. We made it with no violation, but it was close. We were both inattentive and complacent but primarily myself as the pilot not flying, was bored and inattentive. A last minute save prevented a real problem.

11. The controller had just finished a busy 15 session and had performed admirably. As the traffic died down, he sort of mentally kicked back and started to think of other things. During the busy portion, he had released 2 aircraft off a satellite airport and maneuvered traffic around to protect the departure course. Now with it slow, he released 1 aircraft off the satellite airport and descended the only other aircraft he was working through the departure corridor. The other aircraft departed and separation was lost.

12. A controller was working ground control during a slow period. The controller was on position for about 1½ hours. The positions were being combined. The controller was reading and waiting for relief. A Mexicana 727 called for taxi instructions. He taxied the aircraft to runway 25R and started questioning the supervisor about his relief. The Mexicana taxied out of the terminal onto the active runway. The local controller noticed the Mexicana on the runway and advised the ground controller. The ground controller was preoccupied about his relief.

<u>Complacency</u>

1. We routinely get GPWS/ground proximity warnings while fly into CRW/AUP/ROA. During the day, we usually confirm our altitudes, VASI, and radar altimeter. At night, we do the same. The problem is that these warnings are becoming increasingly ignored while IMC if they are happening at about the same location. This could be a problem in the future. It means that these warnings are meaning less and less to crews because of their accuracy. The crews are becoming complacent and almost ignoring these perceived nuisance warnings. The official answer from the training department is that pilot action would never be like that, but the guidelines are being made by guys who don't fly much or enough. The potential is there for big problems.

2. I was flying as a MD-80 first officer from Dallas Fort Worth to DCA. The captain was flying as we approached DCA. The weather was lousy (less than 500') and we planned the ICS to runway 1, which being DCA-based, we had flown many times. As usual for DCA, traffic inbound and outbound was heavy so air traffic control was doing some creative vectoring in order to put spacing between arriving aircrafts in order to allow a departure in between. In our case, we were given an intercept heading for the ICS that put us just inside the outer marker. No problems, we knew the layout, obstacles, etc. However there was one problem, we got glide slope intercept prior to localizer intercept and the autopilot started descending us. Now we were in a position where we didn't really have obstacle clearance and the DCA restricted area to our north. We abandoned the approach and went back around and set up a longer approach. Although the air traffic controller used a poor heading that got us into this fix, our complacency resulted in poor

behavior and degraded performance.

3. It was an early morning departure for a short flight from Albuquerque to Denver. It was the copilot's leg. I've been into Denver a thousand times. It is always a very controlled airport entry with plenty of time to get set up for the approach, even if the weather is bad. This day the weather was marginal, visual flight rules, and Denver was landing to the south. We were approaching the airport from the south over the mountains. Everything was set up for a landing on runway 16 and both pilots were "fat, dumb, and happy." Nearly abeam, the controller issued a new clearance to runway 7. We were at 14,000' and suddenly being turned onto a 12 mile final approach. We were not slowed, not configured, and not ready. The subsequent approach was gross, never really stabilized, never on profile, and significantly high and fast, resulting in a long fast landing. The end result was satisfactory, not unsafe, but totally sloppy and an embarrassment to both pilots. We should have been ready and/or asked for additional time/vectors to get ready if we weren't. Given the situation we ultimately found ourselves in, we should have gone around and set ourselves up for a proper approach. It was all preventable if we had not been so complacent.

4. The first leg of our trip was on Sunday morning flying from Chicago to Raleigh with visual flight rules. The captain was flying. It was uneventful throughout until we were southbound abeam the field for a landing to the north. The controller asked if we could make a short visual final and remain high as long as possible for noise abatement. No sweat, in a 727 if you can see it, you can land on it. We turned a high short final, configured and pointed at the runway – very steep. Finally about one mile out, the captain gave up and went around. No big deal at all to do, but not commonly done (gas, time, looks bad, etc.). He automatically assumed that he could hack it. It was a great decision to go around, but it could have been prevented by better planning or by asking other crewmembers for advice.

5. We were on an international flight to Mexico City. On arrival, we were given an intercept heading for the VOR/DME approach to the southwest. Our navigation equipment on the Airbus A-320 showed that we were on course to intercept final and then it directed a turn to the final approach course. We had not yet shifted to the raw data display. Shortly after we rolled out on final, though still well outside the final approach fix, the controller asked us if we were receiving the VOR. We said yes and immediately called up raw data. We realized that we were several degrees left of our course. We immediately corrected and flew an uneventful approach. We realized that we had experienced map shift, which is fairly common outside the US. The arrival information warned us of this possibility and the captain (who was the pilot flying) had briefed us that he would display raw data for the arrival but he had forgotten. In the airbus, we rarely fly outside the US so we basically never see map shift. We allowed our complacency and trust of the equipment to get the better of us this time. Although the in-flight briefing prior to the approach and the availability of map shift warnings in our paperwork were excellent aids, they don't mean a thing if you don't do what you are briefed to do.

6. We were on a southwest operation at Norfolk. The arrival controller was not working many aircrafts throughout the session. The controller had 2 aircrafts straight-in and our aircraft was on a modified base. The weather at the airport was good visual flight rules

and was shooting visual approaches. The aircraft on base reported that the airport was in sight, but was told to follow traffic on a straight-in. The pilot was above the traffic that they were following and continued on the base over the traffic. At that time, the base aircraft turned away from the airport to start a descent. The controller thought that he would turn in right behind the straight-in. When he didn't, the second straight-in was headed right at him. The controlled didn't take positive action to turn the aircraft.

7. The controller was working a feeder position. Aircraft #1 was a BE-90 eastbound at 15,000 feet. Aircraft #2 was a F-15 southeast descending from 19,000 to 13,000. The aircraft were on converging courses with about 20 miles apart. This scenario is routine and normally would not be a problem however, the controller accepted a handoff on Aircraft #2 without restricting his descent to 16,000. The #2 aircraft never checked in with the controller and descended through Aircraft #1. After reviewing the situation, the controller admitted he was complacent and thought he could work out the problem.

8. On 2 separate occasions while working the arrival radar position at Norfolk, I have had pilots in good visual flight rules weather report Norfolk in sight. After clearing these aircraft for a visual approach to Norfolk and switching them to the control tower, I quit paying attention to the aircraft's flight path. Both of these aircraft entered the flight pattern at Navy Oceana and very nearly landed there. Trusting the pilot in these situations can be hazardous even if they sound like they know what they're doing. You should always monitor the aircraft's flight path to ensure compliance with any given instruction.

9. I cleared an aircraft for take-off on one runway with another aircraft cleared to land on a 4-mile final to a crossing runway. I continued working the aircraft on another runway and in the air. I scanned the area and noticed the aircraft to depart had not started his departure roll. I advised him to expedite his departure for traffic landing the cruising runway. I advised the landing aircraft and eventually the departing aircraft rolled and went through the intersection with the landing aircraft less than a mile on final. This was caused by counting on elements of the system to work as planned (i.e., aircraft to depart) when cleared for take-off without delaying or advising.

10. I was working a traffic helicopter along the interstate, which crossed about ½ mile left-to-right of the 3 parallel runways. It was a busy time of morning for the inbound/outbound rush. We usually cross helicopter and smaller aircraft mid field when transitioning across the field east-to-west. Since there was a gap in the inbound traffic, I obliged the traffic helicopter's request to follow the freeway through. I continued to work my traffic for departure and inbounds further out. I turned when the helicopter remarked about a traffic accident that had just happened below him. Instead of flying straight through the approach corridor, the helicopter had begun to orbit the accident site. I advised the helicopter that there were aircraft approaching his position on final and that he needed to continue eastbound so as not to cause a conflict. My belief in the helicopter continuing eastbound let me relax to the point where him stopping in position had caused problems.

11. It was an early morning operation in the tower during a slow traffic period. The day shift crew had just relieved the midnight shift crew. The controller was working the local control position. After approximately 30 minutes on position without any traffic, a DC-10 checked in for landing approximately 15-18 miles our final. The controller cleared the

DC-10 to land and began talking to his buddies working at the other positions. A B-747 checked in for departure with departure times (flow control). He positioned the B-747 on the runway waiting for the appropriate time to release him. The DC-10 landed above the B-747 on the runway. The controller was complacent because it was slow and he forgot the landing traffic.

12. Both pilots had commuted to Chicago for work after several days off. Both pilots had not had much rest during their days off due to family activities. The trip departed at 13:00 to Orlando and was uneventful. There was a 2½ hour sit in Orlando prior to the second leg to Los Angeles during which time both pilots began to show signs of fatigue. The 2 ½ hours turned into 3½ hours due to a delayed aircraft arrival. The flight took off for the 5½ hour Los Angeles leg into expected good weather. After leveling off, both pilots settled into a long-range cruise mentality, thinking about how soon they would arrive and be able to go to bed. About 1½ hours into the leg, a few radio calls alerted the crew about possible weather activity ahead. This was unexpected and the weather radar was off. By the time the radar was turned on, analyzed, and information processed, it was necessary to initiate an immediate course correction, altitude change, and reassessment of the corrective action. The next 45 minutes involved numerous heading changes and taking the aircraft well off the original planned route. Radar and company communication was used in conjunction with air traffic control to avoid severe weather, but the ride was not too smooth. The end result was no damage and no injuries, but fatigue combined with a good weather mindset resulted in a late reaction to an avoidable problem. Subsequent performance was good, but if all of the information was available earlier it could have prevented a last minute task saturated environment. (FATIGUE)

    A controller was working radar departure control in light traffic (positions are combined). The departure aircraft checked in. The controller climbed and turned the aircraft toward the departure fix and attempted to handoff the aircraft to the center. The aircraft was slow and the computer tag had been intermittent so the handoff did not occur. The controller forgot about the aircraft when the traffic picked up. The aircraft climbed and departed the controller's airspace into the center's airspace without proper coordination. The center called to query about the target. No incident occurred. The controller was initially complacent and did not assure a proper handoff.

APPENDIX C: ANCILLARY CRITICAL INCIDENTS

Forgetting

1. Recently, I forgot to run the taxi checklist prior to take-off and the captain never caught this. Of the 15 or so items on the list only 2-3 can really have killer consequences. As I rotated, the aircraft seemed very heavy. The captain said trim! I looked down and it was set for a weight and CG for our last flight. I compensated smoothly while using two hands. This was a huge mistake (could possibly kill you)! Several things were out of place. The weather conditions were poor and we got to discussing what followed some unusual taxi instructions. Next, we started discussing the captain's previous approach into the airport. I forgot the whole thing!

2. We were pushing back in Boston in a B-757. The captain appeared very rushed and in a hurry to get going. After a normal start sequence he instructed me to call for taxi. I asked him why now and he said just get it. I read back taxi instructions as he pushed up power. I said to stop as did the tower because the crew were still hooked up to the aircraft.

3. We were on an international flight to Mexico City. On arrival, we were given an intercept heading for the VOR/DME approach to the southwest. Our navigation equipment on the Airbus A-320 showed that we were on course to intercept final and then it directed a turn to the final approach course. We had not yet shifted to the raw data display. Shortly after we rolled out on final, though still well outside the final approach fix, the controller asked us if we were receiving the VOR. We said yes and immediately called up raw data. We realized that we were several degrees left of our course. We immediately corrected and flew an uneventful approach. We realized that we had experienced map shift, which is fairly common outside the US. The arrival information warned us of this possibility and the captain (who was the pilot flying) had briefed us that he would display raw data for the arrival but he had forgotten. In the airbus, we rarely fly outside the US so we basically never see map shift. We allowed our complacency and trust of the equipment to get the better of us this time. Although the in-flight briefing prior to the approach and the availability of map shift warnings in our paperwork were excellent aids, they don't mean a thing if you don't do what you are briefed to do.

4. The D-Brite was out of service. The tower local controller failed to pass on this information to his relief. The approach controller forgot the D-Brite was out of service. Approach cleared 3 aircraft for approach to different runways and switched them to the tower. The new local controller cleared all 3 aircraft to land based on the false information. All 3 aircraft went around and barely missed each other. The first local controller was complacent with the relief briefing which was "routine not much going on" and upon receiving the information continued with a normal flow to the tower.

5. A controller was working radar departure control in light traffic (positions are combined). The departure aircraft checked in. The controller climbed and turned the aircraft toward the departure fix and attempted to handoff the aircraft to the center. The aircraft was slow and the computer tag had been intermittent so the handoff did not occur. The controller forgot about the aircraft when the traffic picked up. The aircraft climbed and departed the

controller's airspace into the center's airspace without proper coordination. The center called to query about the target. No incident occurred. The controller was initially complacent and did not assure a proper handoff.

Task Overload

1. I was flying as a MD-80 first officer enroute to Dallas Fort Worth. The air traffic controller cleared us to FL 330. We acknowledged the altitude and started the climb. Several thousand feet later, the controller asked us to check our altitude. We told him and he said we were only cleared to FL 290. After further review (i.e., tapes, etc.) we were shown to be correct. As it turned out, the controller was working two frequencies and had incorrectly given us FL 330 versus another aircraft. No adverse results in this instance but obviously the controller was over-tasked and had ineffective performance.

2. The controller was busy and requested assistance. Everything was then running smooth but continued to be busy. A DH-8 departed northeast bound and began complaining about his altitude request and the altitude he received. As the assistant was busy changing the DH-8's altitude in the FD-10, the controller began to lose focus and a handle on the position. To quiet the DH-8 pilot, the controller climbed him through the altitude of an inbound C-9. The controller never noticed the incident while trying to recover the position to a smooth operation.

3. The controller was working a moderate to heavy load of traffic. Flights of F-15's were departing and recovering to the Air Force Base. A heavy C-5 came inbound and was too high for descent to the Air Force Base. Because of the slow descent profile of the C-5, the controller issued a spiral descent to 10,000 from 28,000. As the C-5 got comfortable with the pattern, the descent rate increased. The controller was too busy to watch and didn't pick up on it. A flight of F-15's outbound and headed for the C-5 were climbed to 15,000. When they were 5 miles apart, the controller realized the C-5 was descending through 15,700. The F-15's were descended to 14,000 and the C-5 stopped at 15,000. This could have been avoided with better preparation and issuance of paper stops, which are extremely useful during busy periods.

4. The final controller was working several aircraft into Norfolk. The controller was busy with landline coordination and establishing speed control on the aircraft. There was a 6-7 mile gap between Aircraft #4 and #6. The controller tried to put Aircraft #5 in between the #4 and #6 aircraft. However, due to task saturation, the controller was late in turning Aircraft #5 on his base leg. The late turn resulted with Aircraft #5 and #6 losing standard separation. The controller was not effective in his timing and projection of flight paths. The incident required the controller to break out both aircraft for resequencing thus compounding the situation.

5. The controller worked in the office and didn't think he would work the floor that day. He had a restless night and was fighting a cold. There were a few sick leaves that day so the controller was called to the floor and assigned the arrival position. The position was busy and the controller was behind the whole session. Traffic calls were missed and frequency changes were late. A MD-80 was still on approach frequency when he approached the runway and had to go around. The MD-80 had to be vectored immediately to avoid

departing slower traffic ahead.

6. The work schedule that we had at the time was 3 nights and days. If you had the midnight, you worked 3 nights, 1 day, and a mid – working a 2 to 10 night shift and then coming back the next morning at 6:00. After getting off work at 2:00 pm, I had to return at 10:00 pm for the mid. I was working the last rush of the day after very little sleep between the 3 shifts. After taking several handoffs, I got behind very fast. I forgot the turn-ons and frequency changes. Luckily, the traffic died and I didn't have much traffic for the rest of the shift.

7. The controller was working a high altitude sector. The weather was instrumental flight rules at EWR and La Guardia. The sector was holding aircraft for both airports. Staffing of the area was low and air traffic controllers were spending almost 2 hours on position. The controller had been extremely busy, rerouting aircraft, coordinating alternate routes, and updating expect further clearance times. Almost all of the holding altitudes were being used. The controller had gotten rid of a few aircraft so he accepted two more. Holding instructions were issued to the new aircraft. Then, the controller realized he had put two aircraft at the same altitude. He immediately issued a descent to Aircraft #1 and turned both aircrafts. Separation was lost. In discussing the event with the controller, he stated he was exhausted and needed a break.

<u>Underprepared</u>

1. Both pilots had commuted to Chicago for work after several days off. Both pilots had not had much rest during their days off due to family activities. The trip departed at 13:00 to Orlando and was uneventful. There was a 2½ hour sit in Orlando prior to the second leg to Los Angeles during which time both pilots began to show signs of fatigue. The 2 ½ hours turned into 3½ hours due to a delayed aircraft arrival. The flight took off for the 5½ hour Los Angeles leg into expected good weather. After leveling off, both pilots settled into a long-range cruise mentality, thinking about how soon they would arrive and be able to go to bed. About 1½ hours into the leg, a few radio calls alerted the crew about possible weather activity ahead. This was unexpected and the weather radar was off. By the time the radar was turned on, analyzed, and information processed, it was necessary to initiate an immediate course correction, altitude change, and reassessment of the corrective action. The next 45 minutes involved numerous heading changes and taking the aircraft well off the original planned route. Radar and company communication was used in conjunction with air traffic control to avoid severe weather, but the ride was not too smooth. The end result was no damage and no injuries, but fatigue combined with a good weather mindset resulted in a late reaction to an avoidable problem. Subsequent performance was good, but if all of the information was available earlier it could have prevented a last minute task saturated environment.

2. This is a story of anticipated mental fatigue where effective techniques meant that nothing happened. We were scheduled in an Airbus A-320 to fly from Vancouver to San Francisco, lay over for about 3 hours, then fly on to Dulles International (landing after midnight). Total duty day with briefing time was about 12 hours. Vancouver's weather was good but there were scattered thunderstorms for San Francisco and heavy thunderstorms (with a good chance of a divert) for Washington. The first leg was

uneventful, except that we planned ahead and arranged to land on the one runway certified for automatic landings, in case we needed to use it in Washington. The captain spent a good deal of time on the layover studying the weather and concluded with the dispatcher that Syracuse, NY was the closest alternate. The aircraft was full of passengers and cargo so we couldn't add any gas; fuel would be tight. Enroute to Washington, we kept updating our weather information with dispatch through our onboard computer and we were able to change our alternate to Pittsburgh, saving about 1,000 lbs of gas to allow more holding time if needed. On arrival, Dulles approach tried to assign us a non-autoland runway, but with low ceilings, reduced visibility, mental fatigue, and wet runways we insisted on the autoland runway. We also briefed a normal and an autoland approach. Except for the ceiling being lower than anticipated, everything was as expected and we made a normal landing. It was extremely effective to plan ahead and prepare for automated assistance to compensate for fatigue. We also kept alert by talking to each other and to dispatch. The weather radar was a superb tool upon arrival. And yes, Starbucks coffee helped too. This was an example of many effective behaviors that helped our performance.

3. We were departing Washington National Airport to the north, as we had done many times. It was a very early takeoff (6:30 am) and I had a long drive (3 hours) so I had left my house at 2:30 am. It was a standard short flight to Chicago, just a low deck of clouds at Washington, then clear, so our prebriefing was short. Just before takeoff, the captain asked me to dial his headings on departure so that the flight director would give him guidance to fly the departure by hand. I said ok without thinking ahead to what that would mean. After gear retraction, he asked for heading select and I set him up for a runway heading. He said no, set me up for the departure. I then dialed in a small left turn, heading 320° to intercept the 328° radial. At that point, he selected autopilot on and dialed in a heading of 300°, which was what was needed to make the tight left turn to avoid flying over the white house which is a real no-no. Once established on the 328° radial, he switched off the autopilot and returned to hand flying. The rest of the flight was uneventful. My ineffective behavior was that I failed to plan ahead and review exactly what my duties on an instrumental flight rule departure from National Airport would be. In good weather, the pilot flying simply turns left up the river visually, an easy thing to do. So I had not figured out what heading he would need. The captain's effective behavior was in figuring out he was getting no help from me and in turning on the autopilot so he could more easily ensure we avoided the white house prohibited area while staying on our climb profile (which is also very restrictive out of Washington National). This was an example of effective behavior on the captain's part, but ineffective support by the first officer.

4. The first leg of our trip was on Sunday morning flying from Chicago to Raleigh with visual flight rules. The captain was flying. It was uneventful throughout until we were southbound abeam the field for a landing to the north. The controller asked if we could make a short visual final and remain high as long as possible for noise abatement. No sweat, in a 727 if you can see it, you can land on it. We turned a high short final, configured and pointed at the runway – very steep. Finally about one mile out, the captain gave up and went around. No big deal at all to do, but not commonly done (gas, time, looks bad, etc.). He automatically assumed that he could hack it. It was a great decision to go around, but it could have been prevented by better planning or by asking other

crewmembers for advice.

Preoccupied

1. While working the midnight shift at LGB tower, I taxied out of BE-76 for a visual flight rule flight following down the coastline. After the aircraft was airborne and headed south, I went back to filling out the nighttime paperwork. Several minutes after take-off I received a call from the pilot asking who the traffic was that narrowly passed off his left. Realizing that I had completely forgotten to provide advisories to this aircraft, I looked up at the tower radar display and there was in fact another aircraft headed up the coastline at the BE-76's altitude. I apologized for my inattention and let the paperwork wait until I had safely handed the aircraft off to the next controller. This incident occurred early in my career and scared me with the "what if's" so much so that it has never happened again.

2. The day shift crew had just relieved the midnight crew. The day shift crew was short on personnel. The oncoming supervisor relieved the local controller. Runway 25R was closed because some men were finishing up some work on the runway. The supervisor was trying to accomplish some of her duties as the supervisor (i.e., making phone calls and some paper work). An aircraft called for departure. She cleared the aircraft for departure on runway 25R with the men and equipment still on the runway (luckily on the departure end). The supervisor was trying to accomplish too many duties and tasks. She did not properly scan her runway and because the men and equipment were at the end of the runway it was difficult for her or the aircraft to see.

3. This story happened to another crew, I only heard about it. This crew flew the exact same 6 ½ flight hour (13 hour workday) trip day after day, month after month. It left JAD and went up the east coast to Worchester, MA. They were over it! The crew was on an assigned heading and was told to intercept a radial on an airway. They flew 6 miles offshore over the Atlantic (about 1-1½ minutes) before air traffic control asked them where they were going. Both guys had to put down their newspapers and look up to see. This crew was ineffective and complacent. Varying the routes would help this situation.

4. I was a MD-80 first officer flying from San Francisco to Dallas Fort Worth and recovering on an arrival profile that I had flow many, many times. Additionally, I was flying with a very experienced captain, who was probably also bored. The result was a lack of attention and the initiation of a very late descent preventing us from making a published altitude restriction. We realized this well into the descent and embarrassingly told the approach controllers of our problem. Luckily it was somewhat of a slow day. There was no conflicting traffic so the controller was able to delete the restriction. Obviously, our boredom could have resulted in a serious problem and degraded performance.

5. During the last day of a 4-day trip, the captain I was flying with became ill during the first leg of 3. The subsequent scramble to get a replacement pilot took 3 hours and threw the day into a complete thrash, but overall it was no big deal, just 2 more legs to Chicago. I'd done it a million times and the weather was fine. The new captain was a bit behind the power curve after being called at home. He was new on the airplane and asked me to fly the first leg so he could catch up. No problem. That leg was uneventful and though we were late, we turned the aircraft quickly in San Francisco and were on our way to Chicago

with the captain flying. Yes he was new but he was qualified and we were only going to Chicago. My mind was on my upcoming days off, what jobs I had to get done at home, and what activities my kids had going on, etc. We began our descent into the Chicago area. It was clear weather and light traffic. As usual, Chicago approach wanted us to keep our speed up, so we did – no problem. We were cleared to continue our descent from 14,000' to 7,000'. I happened to come out of my haze at 10,300' with 320 knots in time to tell the captain to slow down prior to 10,000'. We made it with no violation, but it was close. We were both inattentive and complacent but primarily myself as the pilot not flying, was bored and inattentive. A last minute save prevented a real problem.

6. We were holding aircraft for the Detroit Airport because we were below minimums and all aircrafts wanted to stay at higher altitudes. All aircrafts were in holding patterns and we didn't have much to do. We became bored and started talking to other controllers in the room. After about 20 minutes, a Zawtop L-188 asked if he should turn north. The controller looked at the radar and didn't see this aircraft on the scope. The aircraft was asked his position and he stated 60 miles south of Toledo. The controller then advised the aircraft to fly 360° and waited until he came back on the radar. All aircrafts were in holding, but this aircraft never acknowledged the instructions to hold. Instead of monitoring the position, the controller started talking to other people and had his back turned to the radar.

7. We were on a cross-country flight from Dulles airport to Seattle, WA. We crossed snowy intersection at 12,000' as assigned, but missed a radio call to us telling us to continue down to 7,000'. (The transmission was apparently blocked.) When we got the descent, it was quite late. We subsequently were cleared lower (to 4,000' then 3,000'), but we were still high. We should have really hustled down out of 7,000' but didn't. The controller delayed our approach clearance because there was another aircraft landing on a parallel runway and we didn't have it in sight. Both pilots in our aircraft were looking for the other guy, even the pilot flying, who should have been watching the altitude and realizing how tight our situation was becoming. We were cleared for the visual approach at the instrument final approach fix. When we looked at the runway, we both finally realized we were way too high. The pilot flying called for the next flap setting, but we were too fast to lower more flaps so we decided to go around. The basic ineffective act here was the pilot flying allowed himself to be distracted looking for the other aircraft – that should have been the responsibility of the pilot not flying. The pilot flying would easily have been able to make the approach if he had aggressively managed his altitude. Crew coordination was poor in that the pilot not flying should have backed him up and alerted him to the excess altitude. Crew coordination was good at one point when the pilot not flying realized we were too fast to lower more flaps, despite the other pilot's direction to do so. This was an example of ineffective behavior. The weather was clear and the missed approach was flown safely. However, things would have been worse with a low fuel state and an alternate airport involved.

8. Controller A was training Controller B. Controller A was not really paying attention and was talking with other controllers in the room. The trainee got busy and could no longer handle the traffic load. Three facilities were holding traffic. Instead of the trainer taking over, the trainee had to get his attention. Controller A took over and controlled the situation but a few close calls resulted from his inattention.

9. Controller A was working the high sector. Controller B was working the sector below Controller A. The aircraft departed the low sector climbing to 7,000 feet. Controller B was trying to work out a shift swap and was not paying attention to the task at hand. Controller A climbed the departure even though he had traffic at 8,000. Controller B heard the clearance and advised Controller A to stop the climb. Controller A was more concerned about the shift swap then working traffic.

10. While working the morning shift at Los Angeles approach and feeling under the weather, I decided to ask for sick leave. Due to constant staffing problems, I was told to hang in there for another hour and then I could go home. During the second hour after my request, I was working the departure radar handoff position. I was feeling worse by now and was also mad that I wasn't allowed to go home. There was an unplanned go-around called down to me from the tower, along with the tower assigned aircraft's heading. I relayed to the departure controller the aircraft information but not the aircraft's heading. The departure controller turned the previous departure out of the way of the go-around to ensure separation. The problem occurred when the heading he turned this departure was the same heading given to the go-around and the aircrafts got way too close to each other.

11. A vehicle was cleared onto the runway for a runway check. Shortly afterwards the local controller, who was not paying attention, cleared an aircraft for take-off. Another controller advised the local controller of the vehicle on the runway but it was too late to stop the aircraft and the vehicle ended up taking evasive action.

12. Controller A relieved Controller B with a complete briefing. Aircraft X was on a 4-mile final and Aircraft Y was in position on the runway for departure awaiting previous arrival to exit the runway. All of these conditions were active during the briefing. Controller A assumed the position and started to review his pay statement. He realized the critical situation when Aircraft Y reminded him that he was on the runway ready for departure. Aircraft X was on a short final and had to be sent around. Controller A was not totally into the relief briefing and was more concerned about other matters.

APPENDIX D: SURVEY

Acceptability of Awareness Measures

Please answer all questions to provide accurate information. Questions require that you enter a numerical value or check an alternative.

I. BACKGROUND INFORMATION

Write your age: _______

Indicate your sex:
____ Male
____ Female

Indicate your ethnicity:
____ American Indian or Alaskan Native
____ Asian or Pacific Islander
____ Black (Not of Hispanic origin)
____ Hispanic
____ White (Not of Hispanic origin)

Experience in your present position?
____ less than 1 year
____ 1-2 years
____ 2-4 years
____ 5-9 years
____ 10-14 years
____ 15-19 years
____ 20-24 years
____ 25 or more years

Total experience in this and similar positions?
____ less than 1 year
____ 1-2 years
____ 2-4 years
____ 5-9 years
____ 10-14 years
____ 15-19 years
____ 20-24 years
____ 25 or more years

II. HAZARDOUS STATES OF AWARENESS

The survey examines Hazardous States of Awareness (HSAs). HSAs are natural human processes that occur frequently in everyday life. Most people have experienced an HSA while driving their car. For example, a driver may be stopped at a signal light, thinking about a planned vacation, and fail to notice that the signal light has changed. This HSA is called "mind wandering." Of course, the driver is likely made aware of the signal light change by honking cars. HSAs are often merely minor annoyances; there is little about them that is hazardous. However in complex systems, they can result in dangerous and deadly outcomes. Some HSAs that can occur include:

Boredom: Having to continue performing an uninteresting task.

Complacency: Unwarranted trust that the equipment or system is operating properly.

Mental Fatigue: Perceived tiredness and inefficiency in performing a task.

Mind Wandering: Thoughts unrelated to the task being performed.

Performance Block: Delayed task performance because of engagement with another task.

Thinking about these HSAs <u>for your work situation</u>, please indicate your level of agreement with each of the following statements by entering the appropriate number.

Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)

____ 1. HSAs occur every day in my job.

____ 2. HSAs occur most frequently when there are few tasks for me to perform.

____ 3. HSAs are the most likely reasons for human error in my job.

____ 4. Checklists and other memory aids can reduce the occurrence of HSAs in my job.

____ 5. Aspects of my work schedule (e.g., hours, rotation, shift) are largely responsible for HSAs in my job.

____ 6. Using manual skills to perform some automated tasks can reduce HSAs in my job.

III. ACCEPTABILITY OF MEASURES

For this section, we ask you to engage in futuristic thinking about devices to measure operator states of awareness. Please understand that prototype devices are currently available. However, these devices await advances in technology for integration into complex systems. Consider the following devices that could be used <u>in your work situation</u>.

Device #1: Brain Activity Level Sensing Device

Suppose that a sensing device is attached to your headset that evaluates the level of your brain activity. We know that brain activity fluctuates with the amount of energy and focus that a person gives to tasks at hand. Further suppose that the device is trained to you such that a baseline is established that reflects your optimal level of performance. When your actual performance deviates from the optimal level by unacceptable amounts, the sensing device would activate and provide feedback to you. The feedback could be given directly through the headset or by a display. The feedback could indicate that you are becoming overloaded by task demands, suggesting that you need help or a rest break. Or, it could indicate that your activity has fallen to an extremely low level, suggesting additional tasks to perform to increase brain activity.

Thinking about Device #1 <u>for your work situation</u>, please indicate your level of agreement with each of the following statements by entering the appropriate number.

Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)

____ 7. Feedback from the device would be useful.

____ 8. I would be willing to use the device even if it is somewhat invasive or cumbersome.

____ 9. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.

____ 10. I would not be concerned if my activity level is recorded for others to review.

____ 11. I would not be worried about legal complications if my activity level is recorded.

____ 12. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.

____ 13. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.

____ 14. For task overload situations, coworkers should be signaled automatically to provide help.

Device #2: Eye Movement Tracking Device

Suppose that a miniature camera is either attached to your headset or embedded into a control panel or display. This camera follows and records the movements of your eye. Further suppose that a baseline of activity is established that considers the person, the nature of tasks, and the priority of information that needs to be processed. When eye movements stay away too long from critical locations or information, signals are given either through the headset or a display. The signals would prompt you to refocus attention to a particular location or set of information.

Thinking about Device #2 <u>for your work situation</u>, please indicate your level of agreement with each of the following statements by entering the appropriate number.

Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)

____ 15. Feedback from the device would be useful.

____ 16. I would be willing to use the device even if it is somewhat invasive or cumbersome.

____ 17. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.

____ 18. I would not be concerned if my activity level is recorded for others to review.

____ 19. I would not be worried about legal complications if my activity level is recorded.

____ 20. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.

____ 21. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.

____ 22. For task overload situations, coworkers should be signaled automatically to provide help.

Thank you for taking the time to complete this survey!

APPENDIX E: TABLES

Table 1. Means, Standard Deviations and Correlations for Survey Items

Item	M	SD	1	2	3	4	5	6	7	8	9	10
Hazardous States of Awareness												
1. HSAs occur every day in my job.	3.69	1.12	---									
2. HSAs occur most frequently when there are few tasks for me to perform.	4.02	0.85	.007	---								
3. HSAs are the most likely reasons for human error in my job.	3.51	0.96	.329	-.074	---							
4. Checklists and other memory aids can reduce the occurrence of HSAs in my job.	4.22	0.86	.314	-.061	.206	---						
5. Aspects of my work schedule (e.g., hours, rotation, shift) are largely responsible for HSAs in my job.	3.80	0.92	.057	-.175	.174	-.071	---					
6. Using manual skills to perform some automated tasks can reduce HSAs in my job.	3.54	1.00	-.002	.201	.142	.154	.151	---				
Brain Activity Level Sensing Device												
7. Feedback from the device would be useful.	3.51	1.10	.122	-.065	-.019	.158	.042	.023	---			
8. I would be willing to use the device even if it is somewhat invasive or cumbersome.	2.77	1.18	.037	.055	-.038	.150	-.145	-.031	.607	---		
9. I would like the option of turning off or not using the device in situations where I feel that it would hinder performance.	4.53	0.67	.006	.034	-.126	.111	.075	.081	.000	-.036	---	
10. I would not be concerned if my activity level is recorded for others to review.[a]	2.48	1.28	.013	.111	.136	.187	-.174	.056	.269	.421	-.029	---

Table 1. Continued

Item	M	SD	1	2	3	4	5	6	7	8	9	10
11. I would not be worried about legal complications if my activity level is recorded. [a]	1.90	1.15	-.079	.218	.010	.074	-.248	-.023	.089	.325	-.113	.560
12. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	2.98	0.98	-.033	.157	.011	-.090	-.016	.032	.318	.283	-.167	.272
13. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	3.31	1.05	-.089	.004	-.128	-.043	-.123	-.084	.265	.237	-.006	.338
14. For task overload situations, coworkers should be signaled automatically to provide help.	3.49	0.96	-.121	.037	-.132	-.095	-.037	.016	.250	.217	-.046	.201
Eye Movement Tracking Device												
15. Feedback from the device would be useful.	3.71	0.94	.077	-.005	-.070	.143	.073	.115	.540	.516	-.074	.446
16. I would be willing to use the device even if it is somewhat invasive or cumbersome.	2.88	1.11	.067	.077	-.094	.038	-.162	.004	.490	.779	-.036	.387
17. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.	4.38	0.72	.135	.020	.024	.190	.222	.091	-.056	-.146	.496	-.123
18. I would not be concerned if my activity level is recorded. [a]	2.47	1.27	.004	.141	.117	.145	-.178	.077	.189	.337	.001	.898
19. I would not be worried about legal complications if my activity level is recorded. [a]	1.81	0.98	-.128	.222	.083	.002	-.199	.064	.194	.442	.001	.683

Table 1. Continued

Item	M	SD	1	2	3	4	5	6	7	8	9	10
20. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	2.94	0.94	.030	.165	-.011	-.008	-.014	.132	.324	.297	-.157	.292
21. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	3.20	1.11	-.088	.017	-.135	.017	-.148	-.062	.256	.221	-.022	.357
22. For task overload situations, coworkers should be signaled automatically to provide help.	3.40	1.20	-.166	-.033	-.035	-.102	-.065	-.086	.269	.255	-.121	.216
Demographic Variables												
23. Age	42.3	9.74	-.093	.009	.065	.147	.014	.093	.150	.134	.283	.058
24. Sex (males =1, females = 2)	1.16	0.37	.097	.054	-.205	-.112	-.262	-.292	-.054	-.077	-.020	-.036
25. Years Experience in Current Position	4.65	1.92	-.226	.128	.016	.017	-.086	-.006	-.126	-.045	.122	-.038
26. Years Total Experience	6.11	1.56	-.009	.044	.152	.080	.114	.039	.050	-.008	.329	.054

Table 1. Continued

Item	11	12	13	14	15	16	17	18	19	20	21	22
11. I would not be worried about legal complications if my activity level is recorded. [a]	---											
12. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	.141	---										
13. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	.201	.240	---									
14. For task overload situations, coworkers should be signaled automatically to provide help.	.146	.139	.509	---								
Eye Movement Tracking Device												
15. Feedback from the device would be useful.	.358	.224	.205	.307	---							
16. I would be willing to use the device even if it is somewhat invasive or cumbersome.	.417	.191	.257	.207	.587	---						
17. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.	-.100	-.146	.016	-.038	-.015	-.169	---					
18. I would not be concerned if my activity level is recorded. [a]	.539	.315	.269	.149	.423	.349	-.142	---				
19. I would not be worried about legal complications if my activity level is recorded. [a]	.725	.236	.273	.111	.324	.414	-.154	.674	---			

Table 1. Continued

Item	11	12	13	14	15	16	17	18	19	20	21	22
20. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	.125	.882	.264	.190	.278	.225	-.040	.304	.206	---		
21. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	.245	.244	.907	.476	.300	.265	.068	.284	.323	.282	---	
22. For task overload situations, coworkers should be signaled automatically to provide help.	.173	.190	.573	.866	.347	.284	-.113	.159	.148	.205	.601	---
Demographic Variables												
23. Age	.206	.073	-.034	-.103	-.005	.119	.038	.098	.205	.023	-.032	-.067
24. Sex (males =1, females = 2)	-.010	.034	.053	-.024	-.011	-.027	-.079	-.011	-.138	-.030	-.005	-.038
25. Years Experience in Current Position	.199	-.057	-.041	-.164	-.192	-.048	-.151	-.003	.141	-.185	-.009	-.098
26. Years Total Experience	.130	-.071	-.114	-.064	-.110	-.004	-.020	.122	.113	-.147	-.124	-.034

Table 1. Concluded

Item	23	24	25	26
Demographic Variables				
23. Age	---			
24. Sex (males =1, females = 2)	-.144	---		
25. Years Experience in Current Position	.574	.051	---	
26. Years Total Experience	.736	-.207	.584	---

Note. N = 100. Correlations with absolute values greater than .198 and .262 are significantly different from zero at $p < .05$ and $p < .01$, respectively.

[a] negatively worded.

Table 2. T-tests Between ATC and Pilot Means

Item	ATC	Pilot	t-test
Hazardous States of Awareness			
1. HSAs occur every day in my job.	3.21	3.83	-2.36*
2. HSAs occur most frequently when there are few tasks for me to perform.	4.04	4.01	0.14
3. HSAs are the most likely reasons for human error in my job.	3.17	3.60	-1.89
4. Checklists and other memory aids can reduce the occurrence of HSAs in my job.	3.88	4.31	-2.16*
5. Aspects of my work schedule (e.g., hours, rotation, shift) are largely responsible for HSAs in my job.	3.88	4.31	-2.90*
6. Using manual skills to perform some automated tasks can reduce HSAs in my job.	3.08	3.71	-2.76*
Brain Activity Level Sensing Device			
1. Feedback from the device would be useful.	3.25	3.59	-1.29
2. I would be willing to use the device even if it is somewhat. invasive or cumbersome.	2.54	2.79	-0.89
3. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.	4.54	4.53	0.08
4. I would not be concerned if my activity level is recorded others to review. [a]	2.67	2.34	1.09
5. I would not be worried about legal complications if my activity level is recorded. [a]	2.08	1.77	1.18
6. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	3.13	2.89	1.05
7. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	3.67	3.17	2.04*
8. For task overload situations, coworkers should be signaled automatically to provide help.	3.46	3.46	0.00
Eye Movement Tracking Device			
1. Feedback from the device would be useful.	3.54	3.73	-0.83
2. I would be willing to use the device even if it is somewhat invasive or cumbersome.	2.67	2.89	-0.85
3. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.	4.13	4.46	-1.94
4. I would not be concerned if my activity level is recorded for others to review. [a]	2.79	2.29	1.73

Table 2. Concluded

Item	ATC	Pilot	t-test
5. I would not be worried about legal complications if my activity level is recorded. [a]	2.17	1.64	2.38*
6. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	2.92	2.91	0.01
7. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	3.54	3.07	1.83
8. For task overload situations, coworkers should be signaled automatically to provide help.	3.42	3.34	0.31

Note. N = 94. Items are identified by numbers within content areas.

* $p < .05$.

[a] negatively worded.

<u>Table 4</u>. Continued

Item	Component 1	2	3	4	5	6	7	8
B1. Feedback from the device would be useful.			.758					
E1. Feedback from the device would be useful.			.707					
B6. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.				.922				
E6. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.				.910				
H1. HSAs occur every day in my job.					.785			
H4. Checklists and other memory aids can reduce the occurrence of HSAs in my job.					.711			
H3. HSAs are the most likely reasons for human error in my job.					.607			
B3. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.						.840		
E3. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance.						.802		
H5. Aspects of my work schedule (e.g., hours, rotation, shift) are largely responsible for HSAs in my job.							.825	

Table 4. Concluded

Item	Component 1	2	3	4	5	6	7	8
H6. Using manual skills to perform some automated tasks can reduce HSAs in my job.								.785
H2. HSAs occur most frequently when there are few tasks for me to perform.								.672
Percentage of Survey Variance Accounted for by Component:	14.9	13.5	12.7	9.0	7.5	7.4	6.13	5.62

Note: Items are identified with numbers and content letters (Hazardous, Brain, Eye). Component labels: 1 = Legal Concerns; 2 = Task Overload; 3 = Device Use; 4 = Task Underload; 5 = HSA Occurrence; 6 = Option to Use; 7 = Scheduling; and 8 = Reducing HSAs.

[a] negatively worded.

Table 3. T-tests Between Brain and Eye Device Means

Item	Brain	Eye	t-test
1. Feedback from the device would be useful.	3.51	3.71	-2.03*
2. I would be willing to use the device even if it is somewhat invasive or cumbersome.	2.77	2.88	-1.44
3. I would like the option of turning off or not using the device in situations where I feel that it would hinder my job performance	4.53	4.38	2.14*
4. I would not be concerned if my activity level is recorded for others to review. [a]	2.48	2.47	0.17
5. I would not be worried about legal complications if my activity level is recorded. [a]	1.90	1.81	1.12
6. For task underload situations, I would like to be given additional tasks to perform to increase my activity level.	2.98	2.94	0.85
7. For task overload situations, my supervisor (or significant coworker) should be signaled automatically to provide help.	3.31	3.20	2.35*
8. For task overload situations, coworkers should be signaled automatically to provide help.	3.49	3.40	1.75

Note. N = 100. Items are identified by the same numbers for the two devices.

* $p < .05$.

[a] negatively worded.